THE

# LONGITUDE DISCOVERED

BY THE

# ECLIPSES, OCCULTATIONS, AND CONJUNCTIONS OF JUPITER's PLANETS.

WITH

DESCRIPTIONS of those Refracting and Reflecting TELESCOPES; and of those SECTORS, and that QUADRANT, which are the Instruments necessary for this DISCOVERY, both at Land and Sea.

To which is added,

An *EPHEMERIS* for the latter Half of the YEAR of our Lord 1738.

Containing the

CONFIGURATIONS of *Jupiter*'s PLANETS at Six a Clock every Evening, while *Jupiter* is to be any where seen. With those ECLIPSES, OCCULTATIONS, and CONJUNCTIONS that are useful for the DISCOVERY of the LONGITUDE, both at Land and Sea. Engraven on a Copper Plate.

Humbly Recommended to

The HONOURABLE the COMMISSIONERS appointed by Act of Parliament for the Discovery of the LONGITUDE at SEA.

By WILL. WHISTON, *M. A.*
Sometime Professor of the MATHEMATICKS in the University of *CAMBRIDGE*.

Καὶ πᾶσαι πεδίοιο τελοῦσι, καὶ τρηχεῖς ὄχθαι,
Οὔρεα δ' ὑψήεντα, καὶ ἄγρια κύματα πόντου
Εὔβατα δὴ, καὶ εὔπλοα ἔσσεται ἤμασι κείνοις.

Orac. SIBYLL. L. III.

*LONDON*,
Printed for JOHN WHISTON, at *Boyle*'s Head, *Fleet-Street*.
M DCC XXXVIII.

THE

# LONGITUDE DISCOVERED

BY THE

# ECLIPSES, OCCULTATIONS, AND CONJUNCTIONS

OF

# JUPITER'S PLANETS.

DESCRIB[illegible] Refracting and Reflecting T[illegible] S[illegible] and [illegible] Quadrant [illegible] for this D[illegible] Land and Sea.

To which is added,

An EPHEMERIS for the [illegible] of the YEAR of our Lord 173[illegible].

Containing the

CONFIGURATIONS of Jupiter's PLANETS at Six a Clock every Evening, while Jupiter is to be and where seen. With those ECLIPSES, OCCULTATIONS, and CONJUNCTIONS that are useful for the DISCOVERY of the LONGITUDE, [illegible]

Humbly Recommended to

The Honourable the COMMISSIONERS appointed by Act of Parliament for the Discovery of the LONGITUDE at Sea.

By WILL. WHISTON, M.A.

Sometime Professor of the MATHEMATICKS in the University of CAMBRIDGE.

[illegible]

Ovid. [illegible]

LONDON.

Printed for John Whiston, at Boyle's Head, Fleet Street.

MDCCXXXVIII.

To the HONOURABLE the

COMMISSIONERS

APPOINTED BY

ACT of PARLIAMENT

FOR THE

D I S C O V E R Y

OF THE

LONGITUDE at SEA,

THIS

D I S C O V E R Y

OF THAT

L O N G I T U D E,

Now, at length, rendered practicable at SEA,

I S,

With all due Submission,

Humbly Dedicated by

The AUTHOR.

[illegible] perhaps

[illegible] the Publick [illegible] by Act

of Parliament

for [illegible] for procuring a Re-

ward [illegible]

[illegible]

Longitude at Sea, I believe it does at

length appear, that none of them have

so well deserved the attention of the

Curious, and particularly of the Honour-

able the Commissioners appointed for

that purpose, as [illegible]

[illegible]

# PREFACE.

*AFTER all that has been propo-sed to the Publick since the Act of Parliament pass'd, twenty-four years ago, for providing a Reward to any who should find out a practicable method for Discovering the Longitude at Sea, I believe it does at length appear, that none of them have so well deserved the attention of the curious, and particularly of the Honourable the Commissioners appointed for that purpose, as Mr.* Harrison's *at-*

*tempt*

*tempt for making ſuch a Clock as may go true on ſhipboard*; *and Mr*. Whiſton's *attempt for producing ſuch Refracting and Reflecting Teleſcopes as may ſhew the* Eclipſes, Occultations, *and* Conjunctions of *Jupiter*'s Planets, *and the* Occultations *of fixed Stars by the* Moon *there. Which laſt mentioned method includes the uſe of two New Inſtruments, called the* Longitude Sectors, *now firſt propoſed by Mr*. Whiſton, *as well as of Mr*. Barſton's Quadrant. *Which* Quadrant, *altho' it were at firſt intended by the Author for taking the* Latitude, *in which caſe it has met with great Approbation*; *yet does it moreover ſeem to be the beſt Inſtrument hitherto known for perfecting the Diſcovery of the* Longitude *alſo, whenever neither the riſing nor ſetting of the Sun, Moon, or Stars can be*

*be ſeen at Sea: which is a caſe but too common there alſo. For as this Inſtrument is known to take the Altitude of the heavenly bodies much better and quicker, even at Sea, than any other; ſo is that altitude, when the Horizon is not to be ſeen, the beſt means of knowing the time at the Ship. Without which Knowledge, all Clocks, or Obſervations of* Jupiter's *Planets, or of the Appulſes of the Moon to fixed Stars,* &c. *muſt be to no purpoſe, as to the Diſcovery of the Longitude there.*

*In order to the Explaining which methods by* Jupiter's *Planets, and by the* Occultation *of fixed Stars by the* Moon; *the Author, Mr.* Whiſton, *offers theſe* XXXIV Lemmata, *or Preparatory Propoſitions; and the following* XI Problemata: *immediately including the*

*the Discovery of the Longitude: and that in the exact way of the Geometricians; for greater perspicuity, and evidence of Demonstration.*

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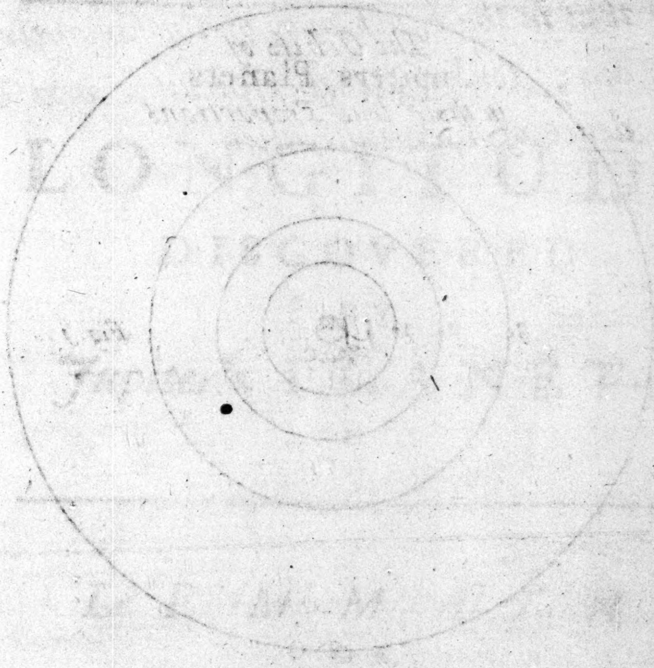
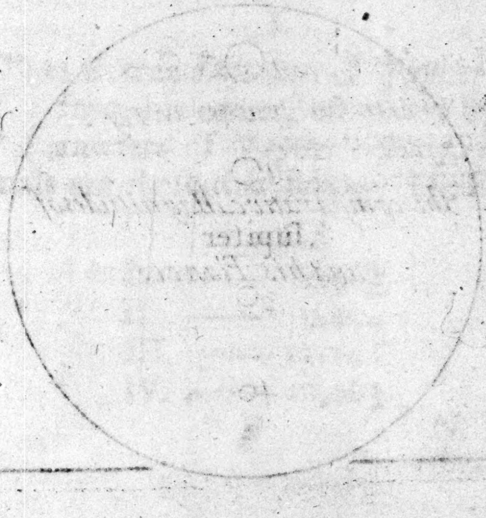




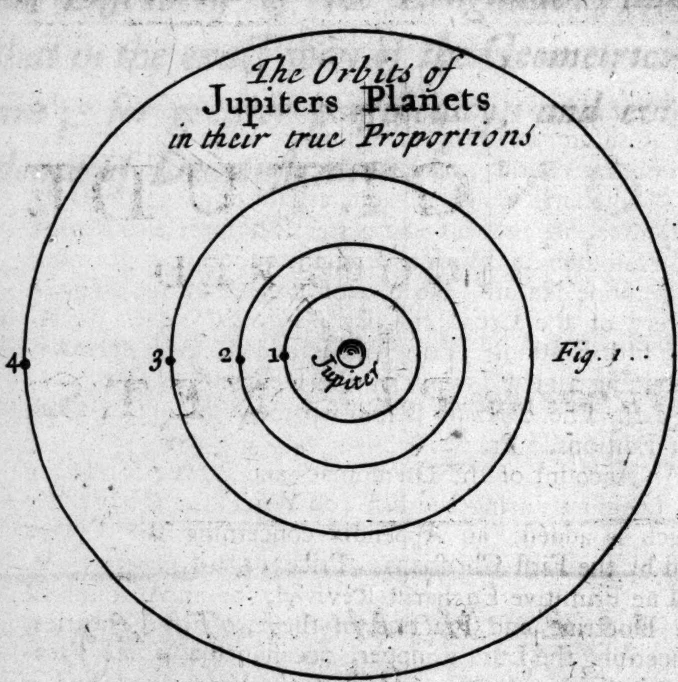
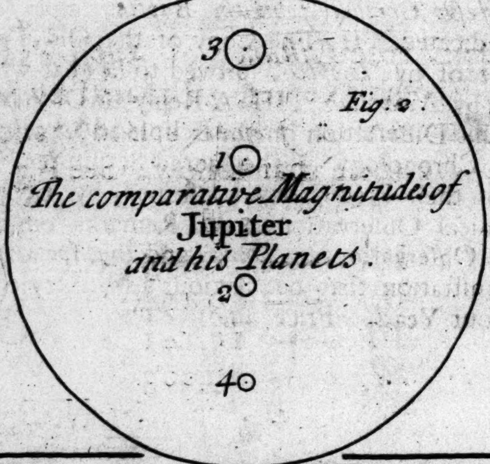

The Orbits of
Jupiters Planets
in their true Proportions
4
3
2
1
Jupiter

Fig. 1.


3
Fig. 2.
1
The comparative Magnitudes of
Jupiter
and his Planets.
2
4

THE

# LONGITUDE DISCOVERED BY *Jupiter's* PLANETS.

## *LEMMATA*: OR, Preparatory PROPOSITIONS.

### I.

THE true *Distances* of *Jupiter's* Planets from his center, estimated by Semidiameters of *Jupiter's* Body, and their decimals are these that follow: See Fig. (1).

| | s. d. |
|---|---|
| I. —— | 5,965 |
| II. —— | 9,494 |
| III. —— | 15,141 |
| IV. —— | 26,063 |



*N. B.* Their

*N. B.* Their old measures, derived from less accurate Observations, were determined to be these that follow:

| | | s. d. |
|---|---|---|
| I. | —— | 5,667 |
| II. | —— | 9,017 |
| III. | —— | 14,388 |
| IV. | —— | 25,299 |

Yet does not this difference in the numbers at all affect the *proportions* of these Planets proper *Distances* from the center of *Jupiter*; but only the quantity of *Jupiter*'s own Diameter. Which, as it used to be stated at 40″, nearly; so, upon Mr. *Pound*'s exacter Observations, Sir *Isaac Newton* at last justly states it at no more than 37″ $\frac{1}{4}$: and thence corrects the old numbers, and gives us those that are more accurate. See his *Principia*, 3d Edition, pag 390, 391.

II.

The *Periodick Months* or Revolutions of these Planets about *Jupiter*, with regard to the fixed Stars, are these; as given us in the same place by Sir *Isaac Newton*.

| | | d. | h. | ′ | ″ |
|---|---|---|---|---|---|
| I. | —— | 1 | 18 | 27 | 34 |
| II. | —— | 3 | 13 | 13 | 42 |
| III. | —— | 7 | 3 | 42 | 36 |
| IV. | —— | 16 | 16 | 32 | 9 |

III.

The *Synodick Months*, or Revolutions of these Planets about *Jupiter*, with regard to the Sun; as given us by all Astronomers, and particularly by Sir *Isaac Newton*, in his *System of the World*, in *English*, pag. 13. and in the first Edition of his *Principia*, p. 403. are these.

| | | d. | h. | ′ | ″ |
|---|---|---|---|---|---|
| I. | —— | 1 | 18 | 28 | 36 |
| II. | —— | 3 | 13 | 17 | 54 |
| III. | —— | 7 | 3 | 59 | 36 |
| IV. | —— | 16 | 18 | 5 | 13 |

*N. B.* Because the three quarters; the halves; and the quarters of these *Synodick Periods* will be of great Use hereafter; I shall here set them down distinctly also.

| | | d. | h. | ′ | ″ |
|---|---|---|---|---|---|
| I. | $\frac{3}{4}$ = | 1 | 7 | 51 | 27 |
| II. | $\frac{3}{4}$ = | 2 | 15 | 58 | 25 |
| III. | $\frac{3}{4}$ = | 5 | 8 | 59 | 42 |
| IV. | $\frac{3}{4}$ = | 12 | 13 | 33 | 54 |
| | | d. | h. | ′ | ″ |
| I. | $\frac{1}{2}$ = | 0 | 21 | 14 | 18 |
| II. | $\frac{1}{2}$ = | 1 | 18 | 38 | 57 |
| III. | $\frac{1}{2}$ = | 3 | 13 | 59 | 48 |
| IV. | $\frac{1}{2}$ = | 8 | 9 | 2 | 36$\frac{1}{2}$ |
| | | d. | h. | ′ | ″ |
| I. | $\frac{1}{4}$ = | 0 | 10 | 37 | 9 |
| II. | $\frac{1}{4}$ = | 0 | 21 | 19 | 28$\frac{1}{2}$ |
| III. | $\frac{1}{4}$ = | 1 | 18 | 59 | 54 |
| IV. | $\frac{1}{4}$ = | 4 | 4 | 31 | 18$\frac{1}{4}$ |

## IV.

The mean *Durations* and *Semidurations* of the Total Eclipses of these Planets, when they are not far remote from their Nodes, and describe Diameters over *Jupiter*'s Shadow, are as follows.

| | | h. | ′ | | | h. | ′ |
|---|---|---|---|---|---|---|---|
| Durations | I. | 2 | 12 | Semidurations | I. | 1 | 6 |
| | II. | 2 | 49 | | II. | 1 | 24½ |
| | III. | 3 | 32 | | III. | 1 | 46 |
| | IV. | 4 | 46 | | IV. | 2 | 23 |

## V.

The like *Durations* and *Semidurations* of the same Planets, while they are under *Occultations* by the body of *Jupiter*, either on this, or the other side, when they are not far remote from their Nodes, and describe Diameters over *Jupiter*'s body, are as follows.

| | | h. | ′ | | h. | ′ |
|---|---|---|---|---|---|---|
| Durations | I. | 2 | 18 | Semidurations | 1 | 9 |
| | II. | 2 | 56 | | 1 | 28 |
| | III | 3 | 40 | | 1 | 50 |
| | IV. | 4 | 54 | | 2 | 27 |

*N. B.* Altho' these apparent Durations on this side *Jupiter* must be somewhat shorter than those beyond him, by passing over somewhat larger arcs of their own Orbits during their Occultations; yet are their Differences so small, as hardly to deserve any allowance in this place.

VI. The

VI.

The *Times* of these several Planets, while they are gradually entring the Penumbra, or imperfect shadow of *Jupiter*'s body, or emerging from it, in their Eclipses; as distinct from their Durations within the total shadow itself, are, by the Observations of Mr. *Lynn*, and many others, found to be nearly as follows. See *Philosophical Transactions*, N°. 393, 394, 396, 401, 402, and 440.

| | ′ | ″ |
|---|---|---|
| I. | 1 | 10 |
| II. | 2 | 20 |
| III. | 3 | 40 |
| IV. | 5 | 30 |

Only we must Note farther, that the Comparison of the Observations shews, that the quantities here set down admit of a good deal of variety; and are at some times considerably larger than at others.

VII.

It appears therefore, from the numbers under the III^d Lemma, that two *Synodick Periods* of the I^st Planet, are shorter than one Synodick Period of the II^d by 20′. 42″.

| | | | | | |
|---|---|---|---|---|---|
| For | 1 | 18 | 28 | 36 | =One Period of the I^st. |
| + | 1 | 18 | 28 | 36 | =Another Period of the I^st. |
| = | 3 | 12 | 57 | 12 | |
| from | 3 | 13 | 17 | 54 | =One Period of the II^d. |
| remains | 0 | 0 | 20 | 42 | |

As

As alſo it appears thence, that two *Synodick Periods* of the II$^{d}$ are ſhorter than one *Synodical Period* of the III$^{d}$ by 1 h. 23′ 48″.

| | | | | | |
|---|---|---|---|---|---|
| For | 3 | 13 | 17 | 54 | =One Period of the II$^{d}$. |
| + | 3 | 13 | 17 | 54 | =Another. |
| = | 7 | 2 | 35 | 48 | |
| from | 7 | 3 | 59 | 36 | =Period of the III$^{d}$. |
| remains | 0 | 1 | 23 | 48 | |

It appears farther, that two *Synodick Periods* of the III$^{d}$. are ſhorter than one ſuch Period of the IV$^{th}$ by 2 d. 10 h. 6′ 1″.

| | d. | h. | ′ | ″ | |
|---|---|---|---|---|---|
| For | 7 | 3 | 59 | 36 | =One Period of the III$^{d}$. |
| + | 7 | 3 | 59 | 36 | =Another. |
| = | 14 | 7 | 59 | 12 | |
| from | 16 | 18 | 5 | 13 | =One Period of the IV$^{th}$. |
| remains | 2 | 10 | 6 | 1 | |

Hence it follows, that theſe ſmall quantities in exceſs are greatly diminiſhed, and, in a manner, worn off in 26 Periods of the IV$^{th}$, in 61 Periods of the III$^{d}$, in 123 Periods of the II$^{d}$, and in 247 Periods of the I$^{ſt}$, when the numbers will ſtand as follows:

| | d. | h. | ′ | ″ |
|---|---|---|---|---|
| 26 Periods of the IV$^{th}$ = | 435 | 14 | 15 | 38 |
| 61 Periods of the III$^{d}$ = | 437 | 3 | 35 | 36 |
| 123 Periods of the II$^{d}$ = | 437 | 3 | 41 | 42 |
| 247 Periods of the I$^{ſt}$ = | 437 | 3 | 44 | 2 |

*N. B.*

*N. B.* Since Mr. *Pound*'s, Tables in every 43 days diminish a single Period of the Ist by 1″ and so in this whole Period 10″. I have set down but 2″ instead of 12″ under its 247 Periods; as this nicety requires.

*Corollary.* All these four Planets therefore return to their former situation, with respect to one another, and to the Sun, in about $437^d$ $3^h$ $40'$ within $1^d$ $13^h$ $28'$ $34''$. Nay the three innermost do the same within the very small quantity of $8'$ $26''$. And accordingly the first three pass through all the varieties of their mutual situations, and return to their former places, with regard to one another, and to the Sun in this Period, of $437^d$ $3^h$ $40'$, and that almost to the utmost nicety. Which therefore is the first *grand Period* to them belonging: and of which *grand Period* particular notice is taken by Mr. *Bradley* upon this occasion; as will be distinctly shewed under the first *Corollary* of the XIth *Lemma* presently.

## VIII.

The Comparative magnitude of these Planets of *Jupiter*; tho' not hitherto sufficiently measured by the Micrometer, or otherwise, so far as I know, seems to be this.

The third is evidently the largest of them all: and, as I guess, about the bigness of the *Earth*, or *Venus*.

The first is the next in largeness; tho' certainly somewhat less than the former; and so not much bigger than *Mars*.

The

The ſecond is a ſmall matter leſſer than the firſt; and ſo not a great deal bigger than *Mercury.*

The fourth is evidently the leaſt of them all; and therefore not much larger than our Moon. See theſe Proportions repreſented in Fig. 2. Monſ. *Caſſini*, by ſtating the diameter of the firſt at the 20th Part of the diameter of *Jupiter*, fairly implies theſe determinations to be not far from the truth. See *Philoſ. Tranſact.* N°. 211.

IX.

The *Diſtances* of theſe Planets from *Jupiter*'s Center are theſe that follow; in our ordinary meaſur'd miles, nearly.

| | | | |
|---|---|---|---|
| Diſtances | I. | — 218000 | miles. |
| | II. | — 348000 | |
| | III. | — 554000 | |
| | IV. | — 972000 | |
| Mean Diſtance of our moon from the Center of our Earth | | — 240000 | miles. |

X.

The *Hourly motions* of theſe Planets about *Jupiter* are as follows, nearly.

| | | | |
|---|---|---|---|
| Motions in an Hour | I. | — 32000 | miles. |
| | II. | — 26000 | |
| | III. | — 20000 | |
| | IV. | — 15000 | |

Mean

| | |
|---|---|
| Mean Motion of our Moon about our Earth in an Hour, nearly, | — 2400 Miles. |

*Corollary.* As therefore all these Moons, or secondary Planets about *Jupiter*, excepting the innermost, are farther off *Jupiter* than our Moon is from our Earth; so is their Velocity, if supposed at equal distances, very much greater. Nor could their projectile motions in any degree balance the vastly greater power of *Jupiter*'s Attraction, arising from his vastly greater magnitude than that of our Earth, had not their Velocities, and, by consequence, the squares of those Velocities, at equal distances, to which that Attraction is always proportional, been vastly greater also.

## XI.

The motions of the I^st^, III^d^, and IV^th^ Planets are tolerably even, and regular. While the motion of the II^d^ is, by far, the most uneven, and irregular of them all: as our Astronomical Observers agree.

*Corollary* (1.) Since therefore the IV^th^ Planet is both the smallest and remotest of them all; Its Attractions cannot very much influence or alter the motions of the three innermost; and their irregularities must chiefly arise from their own mutual attraction or gravitation, acting upon one another: as Sir *Isaac Newton* has demonstrated the Sun, Moon, Planets, and Comets perpetually do.. And since withal the

*Grand Period* of these three, which we have seen to be $437^d\ 3^h\ 40'$, brings them still back to their former situation, we thence learn the true occasion of a kind of Revolution, or Return of their former inequalities in half that Period; or in about 218 days $= 7\frac{1}{4}$ months: which Mr. *Bradley* affirms they do. His words are published, and are these: "I presume, says he, that the "irregular motion of the first Satellite chiefly "arises from the gravity of the other Satellites "towards it: [or rather from its own gravity "towards those others.] For altho' the effect "of the influence that the Satellites have on "each other is most remarkable in the II[d], "whose motion will sometimes be accelerated "or retarded thereby as much as amounts to "30′ or 40′ in time, in the space of about 7 "months; or in half the period in which the "three innermost Satellites return to have "nearly the same position, with respect to them-"selves, and to the shadow of *Jupiter*; yet the "first seems also liable to inequalities that can-"not well be accounted for but from some "such cause as is before mentioned: the effect "of which will not easily be reduc'd to any "rule but from a long and exact Series of Ob-"servations." *Philos. Transact.* N°. 394.

*Corollary* (2.) When therefore we shall have once obtained a compleat sett of Observations of these three Planets for a few of their grand Periods of $14\frac{1}{2}$ months, we shall, probably, be thereby enabled nearly to perfect their Theories, and to compose much exacter Tables than have been

been used hitherto for all their *Eclipses:* As also for all their *Occultations*, and *Conjunctions*. For which purpose it is, in good part, that I now publish this Treatise, and the *Ephemeris* or Scheme of *Configurations* thereto belonging; even before I can reduce my discoveries to that compleat perfection which I aim at in this matter. Which is indeed hindred by nothing so much at present as by the inaccuracy of the Theories of these Planets; and particularly by the great inequalities in the motion of the II$^{d}$.

*Corollary* (3.) Yet, because all the other Planets, primary and secondary, as well as the Comets; that is all the rest of the bodies in our intire Solar System; appear to be more, or less *Eccentrical*, this rational supposal of *mutual influences* ought not to prevent the Observations proper for discovering their *Eccentricities* also. Especially since Mr. *Bradley* has already discovered such an Eccentricity of the IV$^{th}$, as affords its greatest Equation equal to that of *Venus*, or not less than 48′, and that its Apsis, or greatest distance from *Jupiter*, was, at the begining of A. D. 1717. 8 degrees of *Pisces*; Nay, and that the same Apsis goes forward 36′ in a year; or two signs in 100 years. He has also discovered, that in the years $168\frac{2}{3}$, $169\frac{4}{5}$, and 1718, at the distances of *Jupiter*'s revolutions about the Sun, of almost 12 years; the Eclipses of the I$^{st}$ Planet continued at least 2$^{h}$ 20′, while yet in 1677, and 1689, in the middle of such Periods, they did not continue longer than 2$^{h}$ 14′, which difference of Durations

ſeems plainly to imply, that, in the former years, this innermoſt Planet was eclipſed near its *greateſt*; and in the latter near its *leaſt* diſtance from the center of *Jupiter*. Which fairly implies ſome Eccentricity in its Orbit alſo. And as the irregularity of the II[d] is far the greateſt of them all, it is no way unreaſonable to ſuppoſe, that part of this great irregularity may be owing to its Eccentricity alſo. Nor can we, with any Aſſurance, affirm the Orbit of the III[d] to be intirely free from ſuch Eccentricity: tho' it may be comparatively of a very ſmall quantity.

*N. B.* As to the *Inclinations* of the ſeveral Plains of the Orbits of theſe Planets to the Plain of *Jupiter*'s own Orbit; or, which is not very far different, from the Plain of our Eclipick: (for the former Plain is but 1° 20′ different from the other;) together with the places of their *Nodes*; the knowledge of which is neceſſary to the perfect underſtanding of their Theories; take them from Mr. *Bradley*'s determinations, in his Tables of theſe Planets; which, by the favour of Dr. *Halley*, I am now in poſſeſſion of. " As to the Latitudes of theſe Planets, ſays he, It plainly appears by our later obſervations, that the Aſcending *Node* of the IV[th] is now 11°½ in *Aquarius*, and its deſcending *Node* 11°½ in *Leo*; and that the *Nodes* of the III[d] are very near the ſame places. For which reaſon we place the *Nodes* of the two innermoſt there alſo, becauſe the Obſervations do no way forbid

" us

" us so to do: But if these *Nodes* were 40 years
" ago 15° in *Aquarius* and *Leo*, as *Cassini* af-
" firms,(nor have we any other authority equal-
" ly valuable) they must have gone backward
" about one degree in every period of *Jupiter*
" of 12 years. As for the Inclination of the
" plains of these orbits to the plain of *Jupiter*'s
" own orbit, as it is determined by *Cassini*, *i. e.*
" 2° 55′, we still retain it in the other Planets,
" but affirm that the plain of the IV[th] Orbit
" has not quite so great an inclination, and is
" no more than 2° 42′." Altho' it must be confess'd that Mr. *Derham* found the Latitude of the III[d] about *Sept.* 1703 greater than either Mr. *Flamsteed*, or Monsieur *Cassini* had conjectured; and saw it in the *Penumbra*, or imperfect shadow of *Jupiter*, a long while, at the very Pole of *Jupiter*'s body; and took notice that its duration in *Jupiter*'s shadow was no more than two hours; instead of 3$^h$ 32′, which is its proper quantity, when it describes a diameter over that shadow: as has been already observed, under the IV[th] Lemma foregoing. Tho' as to the Nodes and Inclination of the II[d] Planet, I have, I confess, met with no farther particular determination about them. However, in my *Ephemeris*, or Scheme of *Configurations*, I have endeavoured to follow these determinations, and to set each Planet a little northward or southward of *Jupiter*'s center, as their true positions require; that so the careful Observer may the better know the several Planets asunder; and may take notice

at

at what point of *Jupiter*'s body any of them ought to be waited for at their *Emersions* from it.

XII.

If we substract from, or add to, any of the times of *Jupiter*'s Planets coming to their Heliocentrick or Geocentrick *Oppositions*, half their Synodick Periods, we shall gain their foregoing, or following Heliocentrick or Geocentrick *Conjunctions*. The practice of this will be exemplify'd hereafter.

XIII.

If we substract from the places of any of these Planets, counted from their Geocentrick Opposition, at any given time, *one* quarter, or *three* quarters of a Synodick Period; or their places at any given time from *one* quarter, or *three* quarters of such a Period; we shall gain the times of their *Utmost Elongations*. The reason is plain: because these *Utmost Elongations* are always distant *one* quarter, or *three* quarters of such a Period from the time of the Planets position at their Geocentrick Opposition. The practice of this will be exemplify'd hereafter.

XIV.

If we substract from, and add to the times of these Planets position at their *Heliocentrick* Oppositions, their true *Semidurations* in *Jupiter*'s shadow; we shall gain the times of those their *Immersions* and *Emersions* which are stiled

their

their *Eclipses*. The practice of this will be exemplify'd hereafter.

XV.

If we also substract from, and add to the times of these Planets position at the *Geocentrick* Oppositions and Conjunctions, their *Semidurations* under their *Occultations*, either beyond, or on this side of the body of *Jupiter*, we shall gain the times of their *Occultations*, of *Immersions*, or *Emersions* with regard to his body. The practice of this will be also exemplify'd hereafter.

XVI.

Altho' those Eclipses of our Moon which we call *Total* are not strictly such; because the Moon never comes nearer to the *total Shadow* of the Earth than about 80,000 Miles: yet are these Eclipses of *Jupiter's* Planets every one strictly Total. They going very deep into that *total Shadow* of *Jupiter* in every one of their Eclipses. Only we must except the IV[th] Planet, about its greatest Latitude: which cannot then come into his shadow at all, for a long time.

Thus, in Fig. (3) let *AC* represent the Diameter, and *AB* the Semidiameter of the Sun. Let *ac* represent the Diameter, and *ab* the Semidiameter of *Jupiter*. Let the lines *Aae* and *Cce* be tangents of the Sun, and of *Jupiter*; meeting in the vertex of the cone of the shadow of *Jupiter* at *e*, supposing he had no atmosphere: and containing the angle *aec*, or

or *AeC*: and its half, *aeb*, or *AeB*. Let *ad* and *cd* represent the rays of the Sun twice refracted through the bottom of *Jupiter*'s atmosphere; and meeting at *d*, the vertex of that cone of the total shadow: and containing the angle *adc*, and its half *adb*. Draw the lines *aS* and *as* parallel to the axis *eb*; the former for the distance of the Sun and *Jupiter*: and the latter for the distance of *Jupiter*'s IV^th^ or outermost Planet from his center. Draw also the line *gb* to represent the passage of that IV^th^ Planet over the total shadow of *Jupiter*. Then run the following analogies, in order to find the lengths *eB*: *eb*: and *ed*: with the quantities of the angles *aeb*, and *adb*. While *as*: the difference of half the passage of the IV^th^ Planet over the Shadow, from the semidiameter of *Jupiter*, is given from the Observations.

Now if we suppose, with Mr. *Flamsteed*, and Sir *Isaac Newton* formerly, that the Sun's Parallax is no more than 10″ the Earth's distance from the Sun will be about 81,000,000 measured Miles, and *Jupiter*'s distance from him (which is to that, as 52 to 10) will be about 421,000,000 such miles. But if, with Sir *Isaac Newton* at last, we take that Parallax to be 10″ ½ (which is the mean between Mr. *Pound*'s many and most accurate Observations; which always proved to be between 9″ and 12″) the Earth's distance from the Sun will be but 77,000,000, and *Jupiter*'s distance from the Sun but 400,000,000 nearly. In this case the analogies will stand thus:

As

As is *AS*, the difference of the Sun's and *Jupiter*'s Semidiameters, = 9003 Parts : to *Sa*, the distance of *Jupiter* from the Sun, = 400,000,000 :: So is *AB*, the Sun's semidiameter, = 10000 parts: to *Be* = 444,000,000 miles, nearly: which is therefore the length of the intire axis.

From this *Be* thus found, substract *as*, or *Bb* = 400,000,000 : the difference will be *be*, or the axis of *Jupiter*'s shadow, if he had no atmosphere, = 44,000,000 miles, = $\frac{1}{10}$ *Be*, nearly. Then proceed, and say:

As 52 : to 10 :: or as AS the distance of *Jupiter* from the Sun : to the distance of the Earth from the Sun :: So is the sine of the Sun's apparent semidiameter at the earth, = 16′ : to the sine of its apparent semidiameter at *Jupiter*. Or, in such very small angles, :: So is the angle itself at the Earth, = 16′ : to the angle at *Jupiter* = 3′ 5″. Again, As *Be* : to *Bb* :: or nearly as 10 : to 9 :: So is that apparent semidiameter of the Sun at *Jupiter*, = 3′ 5″ to its apparent semidiameter at the vertex *e* = 2′ 46″ = semiangle of the cone *aeb* or AeB. Proceed then farther, and say, As *as* the difference of the semiduration of the IVth Planet, either behind, or on this side *Jupiter*, and of *fg*, his semiduration in the total shadow, or, from the Observations, as 4′ : to 147′ :: So is *sg* = 26,63 semidiameters of *Jupiter*, to *bd* = 978 such semidiameters : = 35,794,800 miles. Take that number out of 44,000,000 the difference will be 8,205,200 miles, = *ed*. Say then

D farther

farther, As $bd, = 3579$ : to $de = 820$ : So is the angle $aeb = 1' \, 46''$, to the angle $ead, = 38' \frac{1}{2} =$ double the greatest horizontal refraction of the rays of light through the bottom of *Jupiter*'s Atmosphere. Which refraction is therefore no more than $19'' \frac{1}{4}$.

*Corol.* (1) This Refraction therefore through the bottom of *Jupiter*'s atmosphere : is to the parallel horizontal refraction through our Earth's atmosphere :: as $19'' \frac{1}{4}$ : to $33' \frac{3}{4} = 2025''$ :: *i. e.* nearly, as 1 to 100.

*Corol.* (2) Since therefore it is well known that the density of our Earth's atmosphere at 22 or 23 miles height, is only the 100th part of its density on the earth's surface: and, by consequence, its refractive power but the 100th part of the other; it follows, that the density and refractive power of *Jupiter*'s atmosphere on *Jupiter*'s surface, is nearly equal to that of ours at 22 or 23 miles altitude: or not much more than the 100th part of the density and refractive power of our atmosphere on the Earth's surface.

*Corol.* (3) Since the $5' \frac{1}{2}$ duration of *Jupiter*'s IVth Planets continuance in the penumbra, or imperfect shadow of *Jupiter*, both in his central *Immersions*, and *Emersions*; as under *Lemma* VI before; is a greater quantity than those 4', by which the passage over the breadth of half the total shadow in Eclipses is less than the passage over *Jupiter*'s bare semidiameter in *Occultations*; it thence appears, that *Jupiter*'s atmosphere makes a sensible shadow somewhat beyond those 4', and indeed must be as high,

at

at least, as the 30th part of his semidiameter. Which is the case of the Earth's atmosphere also.

*Corol.* (4.) Since the Observations shew, that the durations in *Jupiter*'s penumbra, or imperfect shadow, admit of considerable variations; as has been already noted under the VIth *Lemma* already: it appears thence that *Jupiter*'s atmosphere is, at some times, much clearer than it is at others. Which is the case of our own atmosphere also.

*N B.* That I may do Justice here to those Astronomers who have the most contributed to the application of these Eclipses of *Jupiter*'s Planets to the discovery of the Longitude, either at land, or sea, I must inform my Readers, that our own worthy countryman Mr. *Rook*, Professor of Astronomy at *Gresham*-College, is the very first that I have ever met with who thus applied them; and, I suppose, the very first that made Observations of them for that purpose: altho' he died A. D. 1662, just upon his finishing those Observations, and so never lived to perfect his design. Nor did he particularly recommend any of their phænomena, but only the *Immersions* of the first and third, to be made use of; and those only for the perfecting the Geography at land: and this by the comparison of the same *Immersions* as observ'd in different Meridians. Which method, tho' enlarged since to *Emersions*, as well as *Immersions*; and not wholly confin'd to those two Planets; has been, and is still the very same which has been

made uſe of by all Aſtronomers, but moſt frequently by thoſe of the *French* Nation, for that purpoſe, to this very day. However, the Calculation of thoſe Eclipſes being then ſo very imperfect, as hardly to come nearer than to a whole hour, Mr. *Rook* ſaw no poſſibility of coming at the *Longitude at Sea* by ſuch Eclipſes. Of all which matters the Reader may ſee a full account in Biſhop *Sprat*'s Hiſtory of the Royal Society, *pag.* 183—189.

Not many years afterward, Monſ. *Caſſini* ſet about making many more, and much better Obſervations of theſe Eclipſes; and made much exacter Tables for them all; and in particular contrived and publiſhed ſuch excellent Tables for the Eclipſes of the I[ſt], as will render his name famous to all Aſtronomical poſterity. Theſe Tables are the ſame which have been improv'd, and corrected, and republiſhed by Dr. *Halley*, in the *Philoſophical Tranſactions*, N° 214. and then by myſelf, in my Aſtronomical Lectures at *Cambridge*, *pag.* (*Edit. Lat.*) 219—224, and 372—380, and have ſince been reduced to an eaſier form by Mr. *Pound*, and printed in the *Philoſophical Tranſactions*, N° 361. and are thoſe that are made the moſt general uſe of at this day.

'Tis true alſo, that Mr. *Flamſteed* himſelf made no ſmall number of Obſervations, and compoſed Tables for all the Eclipſes of theſe Planets; and contrived a mechanical Inſtrument for finding their ſituations at any time. See *Philoſ. Tranſact.* N° 178.

'Tis

'Tis farther true, that his Relation and Assistant Mr. *Hodgson*, has preserved those Tables of Mr. *Flamsteed's*, and has, in some measure, improv'd them; and from them has now, for several years, given us very valuable Calculations of all their Eclipses, in the *Philosophical Transactions*. Which Calculations have been of great use to me in composing this Treatise about them, as the Reader will perceive hereafter.

'Tis true withal, that Mr. *Bradley* has from *Cassini's*, and Mr. *Pound's*, and his own and others Observations composed and printed about 10 years ago a sett of Astronomical Tables, for these secondary Planets about *Jupiter*, and given them to Dr. *Halley*, as an Appendix, or second part of his Astronomical Tables, the publication whereof hath been very long, and very much desired by the Astronomical World.

I must however do justice to Mr. *Derham*, and to several foreigners, whose Observations of many of these Eclipses have been published in our *Philosophical Transactions*, or elsewhere; and especially to our own long and accurate observer of them, Mr. *Lynn*, of *Southwick*, near *Oundle* in *Northamptonshire*; who will be farther taken particular notice of presently; as having, I think, first of all suggested to the Astronomical World that Phænomenon of these Planets which is the best of all other for the discovery of the Longitude: altho' for the want of sufficient accuracy in several of their Theories, the use of that Phænomenon can be hitherto but rarely of considerable advantage to us.

XVII.

## XVII.

Altho' the *Eclipses* of *Jupiter's* Planets have been hitherto principally considered, and observed by Astronomers; Nay, even few of these Eclipses but those of the Ist have been thought of for the Discovery of the Longitude, either at land or sea; yet do the *Occultations* of them by the body of *Jupiter*, both before and after their central Oppositions, and Conjunctions, but especially in the latter case, highly deserve their consideration, and observation for that purpose. These *Occultations* are usually in number three for one of the Eclipses. And since two of these three are between us, and the body of *Jupiter*; and are therefore no way subject to any penumbra, or refraction through *Jupiter's* Atmosphere; they are, on that account, to be better observed than the Eclipses themselves. Nor ought these Occultations therefore, tho' they require somewhat sharper eyes, and longer Telescopes than those Eclipses, to be wholly neglected when we aim to discover the Longitude by these Planets. The middle times between *Immersions* and *Emersions* being somewhat more easily calculated, and giving us Observations not less fit for our present purpose, than the Eclipses themselves.

## XVIII.

There is also another very remarkable Phænomenon belonging to these Planets, which has been less considered and observ'd than even those

those *Occultations:* I mean their apparent mutual opposite *Transits*, by, or in *Conjunction* with one another. These, by meeting each other, double their natural respective velocities; and determine the times of such their apparent *Transits*, or *Conjunctions* more nicely than either the *Occultations*, or *Eclipses* themselves. These *Transits*, or *Conjunctions* also are usually free from *Jupiter*'s penumbra, and refraction, and too great neighbourhood. All which are known to be great obstructions to the advantageous view of these Planets. Accordingly Mr. *Derham* several times complains of the difficulty of observing these Eclipses near the Opposition of *Jupiter* to the Sun; by reason of the glaring brightness of *Jupiter* himself, just by them at that time: and which most and longest affects those of the innermost, which otherwise are both the best and most numerous of them all. *Philos. Transact.* N° 402. These *Transits*, or *Conjunctions* are in number, compared with the Eclipses, nearly as 3 to 2. They may also be observed to less than a single minute in time: nay, when belonging to the I[st] and II[d], and not too remote from *Jupiter*, they may sometimes be observed to half a minute, or nearer; as our accurate observer of them Mr. *Lynn* informs us, *Philosoph. Transact.* N°. 393. where he moreover, first of all, fairly proposes them to be made use of in the Discovery of the Longitude also. And this very justly; because, when the Theories of these Planets come to be perfect-

ed,

ed, they will determine that Longitude nearer than either the *Occultations*, or *Eclipses* themselves.

*N.B.* The Observations of *Jupiter*'s Planets hitherto made, having been almost wholly confin'd to their *Eclipses*; as has been already noted, which are always near their Oppositions beyond *Jupiter*: The Observations of the *Occultations*, now proposed, being withal ever near their Conjunctions, or Oppositions, either on this, or the other side of *Jupiter*, afford us no Observations about the Quadratures and Octants: which yet ought to be known in order to compleat their Theories. But then, these mutual *Transits*, or *Conjunctions* being sometimes near their Quadratures, and frequently at or near their Octants, will supply the former defect; and afford Astronomers very exact Observations for those Quadratures and Octants, in order to their perfecting those Theories. Nor ought we to forget, that by the means of these mutual *Transits*, or *Conjunctions*, the first, the third, and the fourth Planets, which move more evenly, will already assist us in stating the motions of the second, which are so much more irregular, better than formerly: to the great advantage of this curious part of Astronomy.

## XIX.

Since, as we have taken notice before, there are commonly three Occultations for every Eclipse of these Planets: and three Conjunctions for two Eclipses: And since the first Planet

is

is eclipsed 13 times in 23 days, as Mr. *Pound* truly informs us, *Philosoph. Transact.* N° 361, and the second, half as often, or 6½ times: the third, a quarter as often, or 3¼ times: and the fourth once, and all in the same 23 days: The whole sum of *Eclipses*, *Occultations*, and *Conjunctions*, capable of being made use of in the discovery of the Longitude; I mean this assoon as the Theories and Tables of these Planets are brought to perfection, will be above five times and an half as many as there are days of the year. For 13 and 6½ and 3¼ and 1. are 23¾ Eclipses: to which add about 36 Conjunctions, and about 70 Occultations, the sum will be in all about 130 Phænomena for 23 days, or above 5½ to each day; I mean, through such parts of the year as *Jupiter* and his Planets can be seen. Of which the next *Lemma* will treat particularly.

## XX.

Altho' therefore we make a reasonable allowance (1.) for those 6 weeks in 13 months when *Jupiter* and his Planets are too near their Conjunction with the Sun to be seen at all by any: (2.) for that day time when we cannot see them, tho' they be sufficiently distant from the Sun, and above our horizon: (3.) for such parts of the night time as they are themselves beneath our horizon: and (4.) for the interposition of clouds, which too often, especially in these northern regions obscure the sight of them: Yet shall we still in general, and one with another, have near as many opportunities for view-

 ing

ing one or other of these Phænomena, and for discovering the Longitude by them, as there are days in the year. I mean this still assoon as their Theories are brought to perfection: of which presently. But more of this matter under the IV^th^ Problem hereafter.

## XXI.

From the premisses it is justly to be expected, that a pretty compleat Theory of these Planets may be obtained, upon *proper* and continual *Observations* of all those their *Eclipses*, *Occultations*, and *Conjunctions*, which are visible, in $14\frac{1}{2}$ month; that being, as we have already demonstrated, the grand Period of the motions of those three innermost, which are chiefly to be regarded in these Observations for the discovery of the Longitude. In order to prepare the way for which *proper Observations*, I proceed to the Lemmata following.

## XXII.

If an eye be placed vastly remote from *Jupiter*, and his Planets; as every eye upon our earth always is: And if that eye be in, or very near the same plain with those Planets; as every such eye is: And if that eye view those Planets, as they revolve about *Jupiter*'s center, in circles, concentrical to *Jupiter*; which is very nearly the case of every such eye also: Those Planets will appear to such an eye to move backwards and forwards along those Diameters of their several Orbits, which are perpendicular

pendicular to the line of the earth's distance from *Jupiter:* and their even circular motions, will be truly represented by the uneven divisions made upon such diameters, according to lines of *Sines*, and not otherwise. Thus, in Fig. (4.) to an eye at E: at a vast distance from *Jupiter* at C: altho' each of these Planets be really placed in its own circular circumference MRNS, yet will it appear to our eye, which cannot perceive the difference of the distances on this or on the other side of the Diameter RS, no otherwise than if the Planet were placed in that Diameter. And their apparent distances from *Jupiter*'s center will be the *Sines* of the angles of their real motions from or to *Jupiter*'s center; or, which comes to the same, from or to their Oppositions at *M*, and Conjunctions at *N*, and not otherwise. Thus, *Ad* $\alpha\delta$ on one side; as also *ad* $\alpha\delta$ on the other side, are *Sines* of the angles DCA; DC$\alpha$: and of dC$\alpha$: And the Planet at *A*, or *a*, at *a* or *α*, will appear to the eye at *E*, no otherwise than if it really were placed at *B* and *Ϭ*: at *b* and *Ϭ*. Now, since *AD* is equal and parallel to *BC* and $\alpha\delta$ equal and parallel to *ϬC:* as also *ad* equal and parallel to *bC:* and $\alpha\delta$ equal and parallel to *ϬC:* and since the former are no other than the very *Sines* of their arcs and angles, from or to their Oppositions and Conjunctions, the latter, which are equal and parallel to them respectively, are also the *Sines* of the same arcs and angles, and so every where. This is so obvious a Proposition, as needs no farther illu-

 stration:

ſtration: and is throughly confirmed by all our Obſervations of thoſe Planets.

## XXIII.

If we add or ſubſtract the Time belonging to the *Parallax of the* annual *Orb*, to, or from the Time of the Poſition of any of theſe Planets at the *Heliocentrick* Axis; we gain the Time of their Poſition at the *Geocentrick* Axis: And *vice verſâ*.

Thus if in Fig. (5) *S* repreſent the Sun, *I* the Body of *Jupiter*, and *E* the Earth, in any particular Poſition, the Line *S A* is the *Heliocentrick* Axis: and the Line *E A* the *Geocentrick*. And the Difference between them is the Angle *E I S*, or its Equal, *A I a*: which is called the *Parallax of the* annual *Orb*: and by addition or ſubſtraction reduces the poſitions at one Axis, to thoſe of the other at the ſame Time. So that if one be given, the other is eaſily diſcovered alſo.

*Corollary* (1). Since the *Heliocentrick* and *Geocentrick* places of *Jupiter* are conſtantly ſet down in our vulgar *Ephemerides*, ſuch as thoſe of Mr. *Parker* and Mr. *Weaver*, their *difference*, or the *Parallax of the Orb* is eaſily found by ſubſtracting the leſſer from the greater.

*Coroll.* (2). Since this difference or Parallax vaniſhes both in *Jupiter*'s Oppoſition to, or Conjunction with the Sun, at thoſe times we allow nothing for this Parallax. But then, we are to *ſubſtract* the Parallax out of the *Heliocentrick* place, for 6 $\frac{1}{2}$ months; from the Op-

poſition

poſition to the Conjunction: And from the Conjunction to the Oppoſition we are to add it, for 6 $\frac{1}{2}$ months: in order to gain their *Geocentrick* places. And it may be noted, that as the laſt Oppoſition of *Jupiter* to the Sun was at the end of *Auguſt*, 1737. ſo was the laſt Conjunction *March* 16th, $173\frac{7}{8}$, and the next Oppoſition will be *October* 7th following, as thoſe Ephemerides inform us. An example or two will make this matter eaſy.

*November* 2d. 1737. at 6 in the evening, the Heliocentrick place of *Jupiter* was, by the forementioned Ephemerides, in ♓ 13°. 38′. His Geocentrick place was then, ♓ 24°. 15′. Their difference therefore was 10°. 37′. which was the *Parallax of the Orb* at that time. So *November* 18th the ſame year, at 6 in the evening alſo, the Heliocentrick place of *Jupiter* was ♓ 14°. 21′. His Geocentrick place was then, ♓ 25°. 48′. their difference was 11°. 27′. which was then the *Parallax of the Orb* alſo.

But becauſe the angular motion of theſe Planets is ſufficiently unequal, this Parallax muſt be ſtill reduced to its different intervals in all the four Planets. Thus the firſt Parallax of 10°. 37′. is gone over by the ſeveral Planets in the intervals following:

| | | h. | ′ |
|---|---|---|---|
| I. | in | 1 | 15 $\frac{1}{2}$ |
| II. | in | 2 | 31 |
| III. | in | 5 | 6 |
| IV. | in | 11 | 50 |

Thus

Thus the fecond Parallax, of 11°. 27′. is gone over in the intervals following:

| | | h. | ′ |
|---|---|---|---|
| I. | in | 1 | 20 |
| II. | in | 2 | 40 |
| III. | in | 5 | 25 |
| IV. | in | 12 | 55 |

As a conftant direction for which allowance, the Reader may confult the following Table.

Degrees

Degrees of the Parallax of the Orb; with the hours and minutes corresponding to them: in order to find the *Geocentrick* places of *Jupiter's* Planets, from their *Heliocentrick* places given.

| grad. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h ′ | h ′ | h ′ | h ′ | h ′ | h ′ | h ′ | h ′ | h ′ | h ′ | h ′ | h ′ |
| I | 0 7,1 | 0 14,16 | 0 21,2 | 0 28,3 | 0 35,4 | 0 42,5 | 0 49,6 | 0 56,6 | 1 3,7 | 1 10,8 | 1 17,8 | 1 25 |
| II | 0 14,2 | 0 28,4 | 0 42,6 | 0 56,8 | 1 11 | 1 25,2 | 1 39,4 | 1 53,6 | 2 7,8 | 2 22 | 2 36,2 | 2 50 |
| III | 0 28,7 | 0 57,4 | 1 26,1 | 1 54,8 | 2 23,5 | 2 52,2 | 3 20 | 3 49 | 4 18 | 4 47 | 5 15,7 | 5 44 |
| IV | 1 7 | 2 14 | 3 21 | 4 28 | 5 35 | 6 42 | 7 49 | 8 56 | 10 3 | 11 10 | 12 17 | 13 24 |

These Numbers are thus found

$$\begin{array}{llllll} & {}^{o} & {}^{h} & {}^{o} & {}^{h} & {}' \\ \text{I} & 360 : 42,5 & :: & 1 : & ,118 = 7,1 \\ \text{II} & 360 : 85,28 & :: & 1 : & ,237 = 14,2 \\ \text{III} & 360 : 172 & :: & 1 : & ,477 = 28,7 \\ \text{IV} & 360 : 402 & :: & 1 : & 1,117 = 1^{h}\ 7'. \end{array}$$

*N. B.* The finding the first number gives all the other numbers: which are only 2, 3, 4, *&c.* times those first numbers. And as for the insertion of them upon the *Longitude Sector*, of which presently, there is no difficulty in it: since the very same numbers which exhibit the *Sines* of the 12 first degrees, give the quantities of this *Parallax* also. The divisions being in a manner equal all the way.

## XXIV.

The ways by which the Eccentricity of the Orbits of these Planets may be discovered, are these three: (1.) *That* of noting their greatest errors, with regard to the Calculations from their mean motions: (2.) That by measuring their *Utmost Elongations* from *Jupiter*, by Micrometers: and (3.) That by the different durations of their Occultations, and chiefly those on this side *Jupiter*. These durations in circular motions would be all equal, but in eccentrick and elliptick ones will be as the squares of their different distances from *Jupiter*'s center, reciprocally: and by consequence will be very fit for the accurate determinations of the quantity of such eccentricity. While no more than an hundredth part of difference in eccentricity, becomes a fiftieth part in apparent motion.

*N. B.* It may be here remarked, that the *Utmost Elongations* are at present taken notice of here: Not with any intention of discovering the Longitude by them: for which they are not at all fit; but to afford opportunities at present to such as have very long Telescopes, and very good Micrometers belonging to them, for discovering the *eccentricity* of their Orbits, in order to the perfecting their Theories. After the attainment of which perfection the noting such *Utmost Elongations* may be intirely omitted.

## XXV.

## *A Description of the* Longitude Sector. Fig. (4.)

Take two small planks or boards of deal, each of them somewhat above 6 feet long, and full 5 inches broad. Join them so by hinges, that they may open and shut, as common Sectors do. Paste good white paper upon those inward sides that are to close one upon another: and thereon draw four double strait parallel lines, at proper distances from one another, for so many semidiameters of the Orbits of *Jupiter*'s Planets; to be afterward divided according to so many lines of *Sines*: as has been already explain'd. Then determine a radius, or semidiameter for each of their Utmost Elongations, both ways; in the proportions that agree to their true distances from the center of *Jupiter*. The Radius for the first, or innermost must then be 16,184 inches: and its intire diameter, when the Sector is opened, 32,368 inches. That for the second must be 25,76, and its diameter 51,52. That for the third must be 41,08, and its diameter 82,16. That for the fourth or outmost must be the whole length of the half Sector 72,24, and its diameter 144,48. Besides the semidiameter for *Jupiter*'s body, to be determined by a line drawn cross the instrument on both sides, at the distance of 2,71 inches from the center; and so containing 5,42 inches for his intire diameter.

Theſe meaſures will always repreſent the Orbits of theſe Planets truly, as to their *proportions*, with which we are chiefly concern'd: altho' when the Earth is nearer to, or farther from *Jupiter* and his Planets, than at their mean diſtance, they repreſent what is conſiderably unequal in apparent diameter, or angular meaſure: with which we are very rarely concerned. Then divide each of theſe double lines, or rather a middle line between them, according to the line of Sines: as will be more fully directed preſently. All this is to be done by occult lines, without Ink, or with the leaſt uſe of it poſſible; that the numbers may be no hindrance when the hours, half hours, and quarters, or even the minutes themſelves are to be determined by them. For that is what muſt be done in the next place: I mean to ſet the hours, half hours, quarters, &c. *within* each line, in their proper places; and to note them with black Ink: that they may be ſeen, and uſed upon all occaſions; as will be more fully directed preſently. After which you are to divide the two edges of the Sector, on the ſame plain with the reſt, and on both ſides the center, into inches, and decimals of an inch alſo. But you are ſtill to begin all your numbers for the hours, *&c.* from the middle of the Sector, on the upper of the two lines; or from the Oppoſition beyond *Jupiter:* and to count from your right hand, to your left; till you come to its firſt Utmoſt Elongation: but are

then

then to turn, and count backward, along the lower of the two lines, from your left hand, to your right, till you come to the ſecond Utmoſt Elongation: and then are to return, and, according to the order of nature, to count from your right hand, to your left, till you come to the middle where you began. And thus are you to proceed diſtinctly with the hours, *&c.* of every one of theſe Planets. And all this becauſe, if we could ſee the motions of theſe Planets about *Jupiter* with our naked eyes, they would then appear to go thus, from Weſt to Eaſt perpetually; and would take their conſtant courſes in a way perfectly analogous to that before us.

*N.B.* Becauſe this Scale, which was to include the intire Orbits of all theſe Planets, will not be exact enough for determining their mutual *Conjunctions*; which are of the greateſt conſequence in our preſent deſign; we ought to mark other hours, with the very minutes belonging to them, upon the *outſides* of the forementioned double parallel lines, tho' in the parts neareſt the center only. This ſecond Scale ought to be three times as large as the former: and need not reach quite ſo far as the Orbit of the ſecond Planet in the firſt. For as beyond the third there can be no ſuch mutual *Conjunctions* at all; ſo beyond the ſeconds Orbit there cannot be very many, nor very good ones; becauſe of the length of the Periods of the third and fourth: and becauſe of the comparative

ſlowneſs of their motions there. Whence this neglect of the outmoſt parts, that are almoſt uſeleſs; will permit us to have a larger Scale for the parts moſt uſeful: which are always thoſe not far from *Jupiter*. Not leſs indeed than will give us intire leave to note every ſingle minute of time, in almoſt every one of theſe Planets; without any confuſion: and this almoſt in the very remoteſt parts here made uſe of. Which advantages will abundantly compenſate the forementioned ſmall diſadvantage in the omiſſion, under this Scale, of thoſe parts of the Orbits of the ſecond, third, and fourth Planets which are moſt remote from the center. This only we are to take care of, that we ſufficiently diſtinguiſh the diviſions belonging to this Scale, from thoſe belonging to the other: which will be beſt done by marking both the Sines, and the hours and minutes thereto belonging with *red* Ink; as the other are ſuppoſed already to be marked with *black*.

*N.B.* We may alſo, if we pleaſe, make diſtinct marks upon the *Sines* of the firſt 12 degrees of this Scale for the *Parallax of the Orb*: and this diſtinctly both ways from the center, and for every one of theſe Planets, and with the ſame *red* Ink alſo: That *Parallax* requiring no new diviſions: and properly belonging to the parts neareſt the center, as this Scale for theſe parts of the Orbits do. Its uſe is to denote the place where the perpendicular falls from every Planet upon that diameter on which

the

the Sines are noted: and by the ſubſtraction or addition of their ſemidurations at its poſition in the Heliocentrick Axis in the total ſhadow of *Jupiter*, to indicate the times of the *Immerſions* or *Emerſions* in thoſe Eclipſes; to be compared with the ſame times found by calculation; and to prevent all poſſible error in ſuch calculations.

*N. B.* Becauſe of this double Scale, I ſhall preſently ſet down a double Table of Sines; the latter thrice as large as the former; in order to the ready inſertion of the hours and parts of an hour in their proper places, diſtinctly by each Scale, altho' the Tables for the hours and parts themſelves require no ſuch double Table: but only that each hour and its parts, without any confuſion, be applied to the diviſions in its proper Scale.

## XXVI.

*Tables of* Sines, *for dividing the ſemidiameters of theſe Planets on the Longitude Sector, in the proportions already determined. The latter numbers of inches and decimals belonging to the larger Scale, noted with* red *Ink; and being always juſt thrice as large as the former numbers, for the ſmaller Scale, noted with* black: *and all to be meaſured from the center.*

| Radius. | Inches. | Radius. | Inches. |
|---|---|---|---|
| I. - - - | 16,184 | I. - | 48,552 |
| II. - - | 25,76 | II. | beyond the Sector. |
| III. - | 41,08 | III. | beyond it. |
| IV. - | 72,24 | IV. | beyond it. |

Sines

Sines of 5 Degrees.

| | Inches. | | Inches. |
|---|---|---|---|
| I. - - - | 1,41 | - - | 4,23 |
| II. - - | 2,24 | - - | 6,72 |
| III. - | 3,58 | - - | 10,74 |
| IV. - | 6,29 | - - | 18,87 |

Sines of 10 Degrees.

| | | | |
|---|---|---|---|
| I. - - - | 2,81 | - - - | 8,43 |
| II. - - | 4,47 | - - | 13,41 |
| III. - | 7,22 | - - | 21,66 |
| IV. - | 12,54 | - - | 37,62 |

Sines of 15 Degrees.

| | | | |
|---|---|---|---|
| I. - - - | 4,19 | - - | 12,57 |
| II. - - | 6,66 | - - | 19,98 |
| III. - | 10,63 | - - | 31,89 |
| IV. - | 18,61 | - - | 55,83 |

Sines of 20 Degrees.

| | | | |
|---|---|---|---|
| I. - - - | 5,53 | - - | 16,59 |
| II. - - | 8,81 | - - | 26,43 |
| III. - | 14,06 | - - | 42,18 |
| IV. - | 24,71 | - - | 74,13 |

Sines of 25 Degrees.

| | | | |
|---|---|---|---|
| I. - - - | 6,84 | - - | 20,52 |
| II. - - | 10,89 | - - | 32,67 |
| III. - | 17,37 | - - | 52,11 |
| IV. - | 30,53 | - - | beyond the Sector. |

Sines

Sines of 30 Degrees: or half the Radius.

| | Inches. | Inches. |
|---|---|---|
| I. - - - | 8,09 | - - 24,27 |
| II. - - | 12,88 | - - 38,64 |
| III. - | 20,54 | - - 61,62 |
| IV. - | 36,12 | - - beyond the Sector. |

Sines of 35 Degrees.

| | | |
|---|---|---|
| I. - - - | 9,28 | - - 27,84 |
| II. - - | 14,77 | - - 44,31 |
| III. - | 23,56 | - - 70,68 |
| IV. - | 41,43 | - - beyond it. |

Sines of 40 Degrees.

| | | |
|---|---|---|
| I. - - - | 10,4 | - - 31,2 |
| II. - - | 16,56 | - - 49,68 |
| III. - | 26,4 | - - beyond it. |
| IV. - | 46,43 | - - beyond it. |

Sines of 45 Degrees.

| | | |
|---|---|---|
| I. - - - | 11,44 | - - 34,32 |
| II. - - | 18,22 | - - 54,66 |
| III. - | 29,05 | - - beyond it: |
| IV. - | 51,08 | - - beyond it. |

Sines of 50 Degrees.

| | | |
|---|---|---|
| I. - - - | 12,04 | - - 37,02 |
| II. - - | 19,73 | - - 59,19 |
| III. - | 31,54 | - - beyond it. |
| IV. - | 55,34 | - - beyond it. |

### Sines of 55 Degrees.

| | Inches. | Inches. |
|---|---|---|
| I. - - - | 13,25 | - - 39,75 |
| II. - - | 21,1 | - - 63,3 |
| III. - | 33,65 | - - beyond it. |
| IV. - | 59,14 | - - beyond it. |

### Sines of 60 Degrees.

| | | |
|---|---|---|
| I. - - - | 14,02 | - - 42,06 |
| II. - - | 22,3 | - - 66,9 |
| III. - | 35,57 | - - beyond it. |
| IV. - | 62,55 | - - beyond it. |

### Sines of 65 Degrees.

| | | |
|---|---|---|
| I. - - - | 14,66 | - - 43,88 |
| II. - - | 23,35 | - - 70,05 |
| III. - | 37,23 | - - beyond it. |
| IV. - | 65,46 | - - beyond it. |

### Sines of 70 Degrees.

| | | |
|---|---|---|
| I. - - - | 15,2 | - - 45,6 |
| II. - - | 24,2 | - - beyond it. |
| III. - | 38,6 | - - beyond it. |
| IV. - | 67,7 | - - beyond it. |

### Sines of 75 Degrees.

| | | |
|---|---|---|
| I. - - - | 15,63 | - - 46,89 |
| II. - - | 24,89 | - - beyond it. |
| III. - | 39,68 | - - beyond it. |
| IV. - | 69,72 | - - beyond it. |

Sines

Sines of 80 Degrees.

| | Inches. | Inches. |
|---|---|---|
| I. - - - | 15,94 | - - 47,82 |
| II. - - | 25,37 | - - beyond it. |
| III. - | 40,46 | - - beyond it. |
| IV. - | 71,23 | - - beyond it. |

*N. B.* The Sines of 90 Degrees are the same with the *Radii*, or *Sinus Toti* already set down.

*N. B.* The intermediate Sines have their differences so nearly equal, that they hardly stand in need of distinct Calculations.

*N. B.* This Table is thus made, by the Logarithms.

| | | |
|---|---|---|
| As Radius | = | 10,00000 |
| To Sin. 5° | = | 8,94030 |
| So Log. of 16,184 inches | = | 1,20809 |
| To Log. | = | 0,14838 = |

1,41 inches, as in the Sine of 5° of the *black* Ink, in this Table. And so for ever.

## XXVII.

*A Table of the hourly motions of* Jupiter's *Planets, in degrees, and decimals of a degree, for dividing their Orbits into* hours *and* minutes; *upon the foundation of the foregoing divisions by the* Sines.

I<sup>st</sup> Planet's horary motion in degrees and decimals of a degree.

| h | ° | H | ° |
|---|---|---|---|
| 1 = | 8,475 | 3 = | 25,425 |
| 2 = | 16,950 | 4 = | 33,9 |

 5 = 42,375

| h ° | h ° |
|---|---|
| 5 = 42,375 | 8 = 67,8 |
| 6 = 50,850 | 9 = 76,275 |
| 7 = 59,375, | 10 = 84,75 = 90° — 5,25 |

Say then, 8,475° : 60′ : : 5,25° : 37,2′.

Now $10^h$ 37,2′, taken 4 times, gives $42^h$, 28,6′ = Period of this Planet, and itself is a quadrant to the first utmost Elongation.

*N. B.* These numbers are found thus: $1^h$ = 60′. Then say, $42^h$, 28,6′ : 360° : : $1^h$ : 8,475°, and that number added to itself, as far as 10 times, gives all the other numbers, which serve for dividing the first quadrant from the Geocentrick Opposition.

IId Planet's horary motion, in degrees, and decimals of a degree.

| h ° | h ° |
|---|---|
| 1 = 4,22 | 12 = 50,64 |
| 2 = 8,44 | 13 = 54,86 |
| 3 = 12,66 | 14 = 59,08 |
| 4 = 16,88 | 15 = 63,30 |
| 5 = 21,10 | 16 = 67,52 |
| 6 = 25,32 | 17 = 71,74 |
| 7 = 29,64 | 18 = 75,96 |
| 8 = 33,76 | 19 = 80,18 |
| 9 = 37,98 | 20 = 84,42 |
| 10 = 42,20 | 21 = 88,66 = 90° — 1,34° |
| 11 = 46,42 | |

Then say as before, 4,22° : 60′ : : 1,34° : 19′½.

And $21^h$ with 19′½ taken 4 times, gives 85,18 = $3^d$ $13^h$ 18′ = Period of this Planet: and itself is a quadrant to the first utmost Elongation.

IIId Pla-

III[d] Planet's horary motion, in degrees, and decimals of a degree.

| h | ° | |
|---|---|---|
| 1 = | 2,0931 | |
| 2 = | 4,1862 | |
| 3 = | 6,2793 | |
| 4 = | 8,3724 | |
| 5 = | 10,4655 | |
| 6 = | 12,5586 | |
| 7 = | 14,6517 | |
| 8 = | 16,7448 | |
| 9 = | 18,8379 | |
| 10 = | 20,9310 | |
| 11 = | 23,0241 | |
| 12 = | 25,1172 | |
| 13 = | 27,2103 | |
| 14 = | 29,2034 | |
| 15 = | 31,3965 | |
| 16 = | 33,4896 | |
| 17 = | 35,5827 | |
| 18 = | 37,6758 | |
| 19 = | 39,7689 | |
| 20 = | 41,8620 | |
| 21 = | 43,9551 | |
| 22 = | 46,0482 | |
| 23 = | 48,1413 | |
| 24 = | 50,2344 | = I day. |
| 1 = | 52,3275 | |
| 2 = | 54,4206 | |
| 3 = | 56,5137 | |
| 4 = | 58,6068 | |
| 5 = | 60,6999 | |

| h | ° |
|---|---|
| 6 = | 62,7930 |
| 7 = | 64,8861 |
| 8 = | 66,9792 |
| 9 = | 69,0723 |
| 10 = | 71,1654 |
| 11 = | 73,2585 |
| 12 = | 75,3516 |
| 13 = | 77,4447 |
| 14 = | 79,5378 |
| 15 = | 81,6309 |
| 16 = | 83,7240 |
| 17 = | 85,8171 |
| 18 = | 87,9102 = 90° — 2,0898° = 59′,54″ |

And 1 day, $18^h\ 59'\ 54''$ taken 4 times, is = $171^h\ 59'\ 36'' = 7^d\ 3^h\ 59'\ 36''$ = Period of this Planet, and itself is a quadrant to the first utmost Elongation.

IV^th Planet's horary motion in degrees, and decimals of a degree.

| h | o |
|---|---|
| 1 = | 0,89534 |
| 2 = | 1,79068 |
| 3 = | 2,68602 |
| 4 = | 3,58136 |
| 5 = | 4,47670 |
| 6 = | 5,37204 |
| 7 = | 6,26738 |
| 8 = | 7,16272 |
| 9 = | 8,05806 |
| 10 = | 8,95340 |
| 11 = | 9,84874 |

G 2

12 =

h o

12 = 10,74408
13 = 11,63942
14 = 12,53476
15 = 13,43010
16 = 14,32544
17 = 15,22078
18 = 16,11612
19 = 17,01146
20 = 17,90680
21 = 18,80214
22 = 19,69748
23 = 20,59282
24 = 21,48816 = I day.
1 = 22,38350
2 = 23,27884
3 = 24,17418
4 = 25,06952
5 = 25,96486
6 = 26,86020
7 = 27,75554
8 = 28,65088
9 = 29,54622
10 = 30,44156
11 = 31,33690
12 = 32,23224
13 = 33,12758
14 = 34,02292
15 = 34,91826
16 = 35,81360
17 = 36,70894
18 = 37,60428
19 = 38,49962

| h | o | |
|---|---|---|
| 20 | = 39,39496 | |
| 21 | = 40,29034 | |
| 22 | = 41,18568 | |
| 23 | = 42,08102 | |
| 24 | = 42,97636 | = II days. |
| 1 | = 43,87170 | |
| 2 | = 44,76704 | |
| 3 | = 45,66238 | |
| 4 | = 46,55772 | |
| 5 | = 47,45306 | |
| 6 | = 48,34840 | |
| 7 | = 49,24374 | |
| 8 | = 50,13908 | |
| 9 | = 51,03442 | |
| 10 | = 51,92976 | |
| 11 | = 52,82510 | |
| 12 | = 53,72044 | |
| 13 | = 54,61578 | |
| 14 | = 55,61112 | |
| 15 | = 56,40646 | |
| 16 | = 57,30180 | |
| 17 | = 58,19614 | |
| 18 | = 59,09148 | |
| 19 | = 59,98682 | |
| 20 | = 60,88216 | |
| 21 | = 61,77740 | |
| 22 | = 62,67274 | |
| 23 | = 63,56808 | |
| 24 | = 64,46342 | = III days. |
| 1 | = 65,35876 | |
| 2 | = 66,25410 | |
| 3 | = 67,14944 | |

4 =

| | |
|---|---|
| h | ° |
| 4 | = 68,04478 |
| 5 | = 68,94012 |
| 6 | = 69,83546 |
| 7 | = 70,73080 |
| 8 | = 71,62614 |
| 9 | = 72,52148 |
| 10 | = 73,41682 |
| 11 | = 74,31216 |
| 12 | = 75,20750 |
| 13 | = 76,10284 |
| 14 | = 76,99818 |
| 15 | = 77,89352 |
| 16 | = 78,78886 |
| 17 | = 79,68420 |
| 18 | = 80,57954 |
| 19 | = 81,47488 |
| 20 | = 82,37022 |
| 21 | = 83,26560 |
| 22 | = 84,16094 |
| 23 | = 85,05628 |
| 24 | = 85,95162 = IV days. |
| 1 | = 86,84696 |
| 2 | = 87,74230 |
| 3 | = 88,63764 |
| 4 | = 89,53298 = 90 — 0,46702 |

Then say as before, $0{,}89534^{\circ} : 60' :: 0{,}46702^{\circ} : 31' \frac{1}{4}$.

And $4^{d}\ 4^{h}\ 31'\ 15''$ taken 4 times gives $402^{h}\ 5' = 16^{d}\ 18^{h}\ 5'$ = Period of this Planet: and itself is a quadrant to the first utmost Elongation.

*N. B.* These

*N. B.* These Tables are sufficient for dividing the first quadrants, where the hours begin at the center; and by allowing the difference of those hours from the center in the second quadrants, as the Planets appear to return along the same Semidiameters, will serve for the divisions of that also. But then the third quadrants, not beginning with compleat hours, and having no divisions parallel to them yet made for their guidance, must have distinct Tables made for them, as follows. In order to which find the parts of the first hours thus, for the several Planets.

| | ′ | degrees. | | ′ | degrees. |
|---|---|---|---|---|---|
| I. | 60 : | 8,475 | :: | 45,7 : | 6,455 |
| II. | 60 : | 4,22 | :: | 21 : | 1,47 |

III. Begins naturally with an hour very nearly, so the numbers for the first quadrant serve for this also.

IV. 60 : 0,89534 :: 57,4 : 0,85555

To which last numbers those for an hour are to be still added, as follows.

I.

| h | ° |
|---|---|
| 1st = | 6,455 |
| + | 8,475 |
| 2d = | 14,930 |
| 3d = | 23,405 |
| 4th = | 31,88 |
| 5th = | 40,355 |
| 6th = | 48,830 |
| 7th = | 57,305 |

8th =

| h | ° |
|---|---|
| 8 | = 65,780 |
| 9 | = 74,255 |
| 10 | = 82,730 |
| + | 2,020 |
| | = 84,75 = 90° − 5,25° |

Then say, as before, 8,475° : 60′ :: 5,25° : = 37,2′, which, with half the Period 21$^{h}$ 14′ 18″ and the 10 hours, are = 1$^{d}$ 7$^{h}$ 51′ 27″ and very nearly equal to three quarters of the Period of this Planet: and itself is a quadrant, to the second Utmost Elongation.

II.

| h | ° |
|---|---|
| 1 | = 1,47 |
| + | 4,22 |
| 2 | = 5,69 |
| 3 | = 9,91 |
| 4 | = 14,13 |
| 5 | = 18,35 |
| 6 | = 22,57 |
| 7 | = 26,79 |
| 8 | = 31,01 |
| 9 | = 35,23 |
| 10 | = 39,45 |
| 11 | = 43,67 |
| 12 | = 47,89 |
| 13 | = 52,11 |
| 14 | = 56,33 |
| 15 | = 60,55 |
| 16 | = 64,77 |
| 17 | = 68,99 |

| h | | ° |
|---|---|---|
| 18 | = | 73,21 |
| 19 | = | 77,43 |
| 20 | = | 81,65 |
| 21 | = | 85,87 |

Now 85,87 + 422 = 90,09° and 90,09° — 1,47° = 88,62° = 90° — 1,38°.

Then say, as before: 4,22° : 60′ :: 1,38° : 19′ 36″, which, with half the Period 1$^d$ 18$^h$ 38′ 57″, and the 21$^h$ is 2$^d$ 15$^h$ 58′ 33″, and is very nearly equal to three quarters of the Period of this Planet; and itself is a quadrant to the second Utmost Elongation.

III.

| h | | ° |
|---|---|---|
| 1 | = | 2,093 |
| | + | 2,093 |
| 2 | = | 4,186 |
| 3 | = | 6,279 |
| 4 | = | 8,372 |
| 5 | = | 10,465 |
| 6 | = | 12,558 |
| 7 | = | 14,651 |
| 8 | = | 16,744 |
| 9 | = | 18,837 |
| 10 | = | 20,930 |
| 11 | = | 23,023 |
| 12 | = | 25,116 |
| 13 | = | 27,209 |
| 14 | = | 29,302 |
| 15 | = | 31,395 |
| 16 | = | 33,488 |
| 17 | = | 35,581 |

| h | | ° | |
|---|---|---|---|
| 18 | = | 37,674 | |
| 19 | = | 39,767 | |
| 20 | = | 41,860 | |
| 21 | = | 43,953 | |
| 22 | = | 46,046 | |
| 23 | = | 48,139 | |
| 24 | = | 50,232 | = I day. |
| 1 | = | 52,325 | |
| 2 | = | 54,418 | |
| 3 | = | 56,511 | |
| 4 | = | 58,604 | |
| 5 | = | 60,697 | |
| 6 | = | 62,790 | |
| 7 | = | 64,883 | |
| 8 | = | 66,976 | |
| 9 | = | 69,069 | |
| 10 | = | 71,162 | |
| 11 | = | 73,255 | |
| 12 | = | 75,348 | |
| 13 | = | 77,441 | |
| 14 | = | 79,534 | |
| 15 | = | 81,627 | |
| 16 | = | 83,720 | |
| 17 | = | 85,813 | |
| 18 | = | 87,906 | |
| 19 | = | 89,999 | |

So $1^d\ 19^h$ taken four times is $7^d\ 4^h$ which is very nearly equal to the Period of this Planet: and itſelf is a quadrant to the ſecond Utmoſt Elongation.

IV.

| h | ° |
|---|---|
| 1st = | 0,85555 |
| + | 0,89534 |
| 2 = | 1,75089 |
| 3 = | 2,64623 |
| 4 = | 3,54157 |
| 5 = | 4,43691 |
| 6 = | 5,33225 |
| 7 = | 6,22759 |
| 8 = | 7,12293 |
| 9 = | 8,01827 |
| 10 = | 8,91361 |
| 11 = | 9,80895 |
| 12 = | 10,70429 |
| 13 = | 11,59963 |
| 14 = | 12,49497 |
| 15 = | 13,39031 |
| 16 = | 14,28565 |
| 17 = | 15,18099 |
| 18 = | 16,07633 |
| 19 = | 16,97167 |
| 20 = | 17,86701 |
| 21 = | 18,76235 |
| 22 = | 19,65769 |
| 23 = | 20,55303 |
| 24 = | 21,44837 = I day. |
| 1 = | 22,34371 |
| 2 = | 23,23905 |
| 3 = | 24,13439 |
| 4 = | 25,02973 |
| 5 = | 25,92507 |

6 = 26,

| h | | o |
|---|---|---|
| 6 | = | 26,82041 |
| 7 | = | 27,71575 |
| 8 | = | 28,61109 |
| 9 | = | 29,50643 |
| 10 | = | 30,40177 |
| 11 | = | 31,29711 |
| 12 | = | 32,19245 |
| 13 | = | 33,08779 |
| 14 | = | 33,98313 |
| 15 | = | 34,87847 |
| 16 | = | 35,77381 |
| 17 | = | 36,66915 |
| 18 | = | 37,56449 |
| 19 | = | 38,45983 |
| 20 | = | 39,35517 |
| 21 | = | 40,25051 |
| 22 | = | 41,14585 |
| 23 | = | 42,04119 |
| 24 | = | 42,93653 = II days. |
| 1 | = | 43,83187 |
| 2 | = | 44,72721 |
| 3 | = | 45,62255 |
| 4 | = | 46,51789 |
| 5 | = | 47,41323 |
| 6 | = | 48,30857 |
| 7 | = | 49,20391 |
| 8 | = | 50,09925 |
| 9 | = | 50,99459 |
| 10 | = | 51,88993 |
| 11 | = | 52,78527 |
| 12 | = | 53,68061 |
| 13 | = | 54,57595 |

| h | | ° | | |
|---|---|---|---|---|
| 14 | = | 55,47129 | | |
| 15 | = | 56,36663 | | |
| 16 | = | 57,26197 | | |
| 17 | = | 58,15731 | | |
| 18 | = | 59,05265 | | |
| 19 | = | 59,94799 | | |
| 20 | = | 60,84333 | | |
| 21 | = | 61,73867 | | |
| 22 | = | 62,63401 | | |
| 23 | = | 63,52935 | | |
| 24 | = | 64,42469 | = | III days. |
| 1 | = | 65,32003 | | |
| 2 | = | 66,21537 | | |
| 3 | = | 67,11071 | | |
| 4 | = | 68,00605 | | |
| 5 | = | 68,90139 | | |
| 6 | = | 69,79673 | | |
| 7 | = | 70,69207 | | |
| 8 | = | 71,58741 | | |
| 9 | = | 72,48275 | | |
| 10 | = | 73,37809 | | |
| 11 | = | 74,27343 | | |
| 12 | = | 75,16877 | | |
| 13 | = | 76,06411 | | |
| 14 | = | 76,95945 | | |
| 15 | = | 77,85479 | | |
| 16 | = | 78,75013 | | |
| 17 | = | 79,64547 | | |
| 18 | = | 80,54081 | | |
| 19 | = | 81,43615 | | |
| 20 | = | 82,33149 | | |
| 21 | = | 83,22683 | | |

| h | | o |
|---|---|---|
| 22 | = | 84,12217 |
| 23 | = | 85,01751 |
| 24 | = | 85,91285 = IV days. |
| 1 | = | 86,80819 |
| 2 | = | 87,70353 |
| 3 | = | 88,59887 |
| 4 | = | 89,49421 = 90 — ,50579 |

Then ſay, 0,89534°: 60′ :: 50579°: 33′ 51″ which with half the period in days and hours $8^d\ 9^h\ 0'\ 00\frac{1}{2}''$ and theſe $4^d\ 4^h$ are = $12^d\ 13^h\ 33'\ 51''$ and very nearly equal to three quarters of the Period of this Planet: and itſelf a quadrant, to the ſecond Utmoſt Elongation.

*N. B.* Theſe latter Tables are ſufficient for dividing the third Quadrants, where the hours do not begin at the center: and by allowing the difference of theſe hours from the center in the fourth Quadrants, as the Planets appear to return along the ſame ſemidiameters, they will ſerve for the diviſions of that alſo.

## XXVIII.

### *A Deſcription of the Longitude* Refracting Teleſcope.

This is no other than ſuch a Refracting Teleſcope, of nine foot long, which has *ſeven* Object Glaſſes inſtead of *one*, all of the ſame focal length, as ground together on the ſame tool; and placed in the ſurface of a ſphere of the ſame radius. It has, like other Teleſcopes, only

only one Eye Glafs, but that a very broad one, of 2 ½ inches diameter. Its Tube is much wider at the Object Glaffes, than at the Eye Glafs. Its intention is to bring *Jupiter* and his Planets to the eye, notwithftanding the rolling of a fhip at fea. For that rolling can do no more than remove thofe Objects apparently from one Object Glafs to another; while they ftill come all to the eye through fome one of them, and through the fingle Eye Glafs; in the very fame manner as if there were but a fingle Object Glafs alfo; as in other Telefcopes. Whether we fhall be ever obliged to have more than feven Object Glaffes, as we eafily may, experience only can fully determine. I believe that if we can procure a confiderably broader Eye Glafs, as one of three inches, inftead of this of 2 ½ inches: which I have not hitherto been able to do: we fhould have no great occafion for more than the prefent number of feven. For fince common Telefcopes of this length have ufually Eye Glaffes little or nothing broader than one inch; this Telefcope, of feven Object Glaffes, and one Eye Glafs of three inches broad; has about 63 times the advantage for finding and keeping an Object, which the other have. Since by its feven Object Glaffes thofe advantages become fevenfold; and by the fquare of three to the fquare of one no lefs than ninefold. Now $7 \times 9 = 63$.

*N. B.* It is to be here noted farther, that this Telefcope being too long and unweildy to be

be managed by the bare arms of the Observer, must be placed on a ball and socket, or what is equivalent thereto; must be placed near the ship's center of motion; (which is where the surface of the sea produced would intersect the main mast;) and must be prudently guided by the Observer, that it may be as little as possible diverted from *Jupiter*, during the times of Observation.

## XXIX.

### *A Description of the Longitude* Reflecting Telescope.

This is a new sort of *Reflecting Telescope*, of Mr. *Gregory*'s, or Mons. *Cassegrain*'s form, so much used of late: The focal length of my former large Reflecter, which was of Metal, was seven foot, or 84 inches; and, by consequence, the length of its Tube, lined with black velvet, little above half so long, or 3 ½ foot, whose breadth or Diameter was 4 ½ inches: and its back aperture, with its small Reflecter and Eye Glass, were all of them about 1 ¼ inches in Diameter, and the focal length of the Eye Glass was the same. They were also circular: and the Reflecter was a circular plain. These measures were so large on purpose, in order to take in as great an area in the heavens as might be, without losing the great advantage of *reflections* above *refractions*. That former Telescope took in a full degree of a great circle at once, in diameter: or a circular space about four times as large as the Sun, or Moon, *i. e.* in diameter

four times, and in area ſixteen times as large as the circle of *Jupiter*'s remoteſt Planet: whoſe apparent diameter is little or nothing above half the apparent diameter of the Sun or Moon.

The corrected meaſures I now pitch upon, after ſome trials of the former, are theſe. The focal length of the large Reflecter is to be five feet, or 60 inches: and, by conſequence, the length of its Tube $2\frac{1}{2}$ feet, or 30 inches. Its breadth, or diameter, is to be full 6 inches. The breadth of its back aperture, and Eye Glaſs, not leſs than $1\frac{1}{2}$ inch, and the *charge*, or focal length of the Eye Glaſs about one inch: Its ſmall Reflecter is to be a flat circle, as before, but at leaſt 2 inches in diameter. This Teleſcope will then magnify objects in diameter 60 times, and will be abundantly ſufficient for our Obſervations of *Jupiter*'s Planets, and of the Occultations of the fixed Stars by the Moon; ſuch a Teleſcope taking in above three diameters of the Sun or Moon at the ſame time; or including a circular ſpace above nine times as large as is the area of either of their bodies. Nor will this breadth of the ſmall reflecter intercept more than a ninth part of the rays of light which would otherwiſe fall upon the great one; while, even the common reflecters, which can view nothing far from the axis of viſion, intercept about a ſixteenth part of them.

*N. B.* One thing muſt here be farther explained; and it is this; that becauſe, as Sir *Iſaac Newton* grants, when he was explaining the great advantages of Reflection above Re-

fraction in Telescopes, that still more rays of light are transmitted in refractions through glass, than are sent back by metal in reflections, *Philos. Transact.* N° 80. and N 82. the breadth of the great reflecter ought to be as large as can conveniently be ground, and used, that so the *charge*, or power of magnifying by a small Eye Glass, may not want a sufficient quantity of rays to shew these Planets with sufficient clearness. Tho' I suppose this great breadth of the principal reflecters might be spared, if they could be made of glass; which has been often attempted, but never yet brought to perfection.

*N. B.* That these Eclipses of *Jupiter*'s Planets have been esteemed the best method for discovering the Longitude; and that these Refracting and Reflecting Telescopes are capable of discovering those Eclipses, Occultations, and Conjunctions of *Jupiter*'s Planets, with sufficient accuracy, even at Sea, assoon as the Ports are settled, take the following testimonies of Mr. *Flamsteed*, Mr. *Witty*, or Mr. *Hodgson*, Dr. *Halley*, and Mr. *Hadley*; all Persons of great skill in these matters.

Mr. *Flamsteed's* words are these: *Philos. Transact.* N° 151. "The Eclipses of *Jupiter*'s "Satellites have been esteem'd, and certainly "are, a much better expedient for the disco-"very of the Longitude, than any yet known; "by reason that they happen frequently; and "are easily observable with a [refracting] Te-"lescope of 12 feet, or, for need, with one

" of 8." Mr. *Witty*'s, or Mr. *Hodgson*'s words are these, in Mr. *Hodgson*'s *System of the Mathematicks*, Vol. I. pag. 378. "When we " consider the great number of these Eclipses " every year; there being more visible in one " year, than there are days in it; and, conse- " quently, but few nights when *Jupiter* may " be seen, and which is near eleven months in " the year; but that an Eclipse of one or other " happens; and sometimes two or three in a " night: the easiness with which these Obser- " vations may be made; there requiring only " a Telescope of eight or ten foot in length; " which may be almost managed with the " hand: and the little likelihood there is of " missing the times of ingress or egress; they " being in a manner instantaneous: and, lastly, " the great exactness to which they would " give the difference of Longitude: it being " certainly as exact as the Latitude at present " can be taken: It is much to be wonder'd at, " that the more skilful part of our Seamen " have so long neglected them; and especially " in the several ports into which they sail."

Dr. *Halley*'s words are these: *Philos. Transact.* N° 214. "The method the *French* have used " to determine the Longitude of their places, is " by the Observation of the Eclipses of the first " Satellite of *Jupiter*; which they find almost " instantaneous; and, with good Telescopes, " discernable almost to the very opposition of " *Jupiter* to the Sun. And it may be said, " that this account of the Longitudes observed,

"has put it past doubt, that this is the very best "way, could portable Telescopes suffice for the "work." Dr. *Halley* adds, "However, before "Sailors can make use of this art of finding the "Longitude, it will be requisite that the coast "of the whole ocean be first laid down truly: "for which work this method, by the Eclip-"ses of *Jupiter*'s Satellites, is most apposite. "And it may be hoped, that either a true "Geometrick Theory of the Moon may be "discovered, by the time the Charts are com-"pleated; or else that some invention of "shorter Telescopes may suffice to shew the "Eclipses of the Satellites at Sea." And in the Appendix to the 2d Edition of *Street*'s *Caroline Tables*, the same Dr. *Halley* assures us, that "He had found it only needed a little "practice, to be able to manage a five or six "foot Telescope, capable of shewing the Ap-"pulses or Occultations of the fixed Stars by "the Moon, on shipboard, in moderate wea-"ther:" And elsewhere; *Philos. Transact.* No. 191. and *Abridgment*, Vol. I. pag. 647. "It "will be fit to give the Reader this informa-"tion; *viz.* that the moments of these Eclip-"ses may be, with sufficient distinctness, ob-"served, with a Tube of eight, or even seven "feet, which is easily portable: and more "especially in the outer Satellites. I mean "this in case the Aperture of the Object Glass "be 2 ½ or three inches. For by that means "a very great quantity of the refracted rays "of light will come to the Eye; which will "render

" render those little stars visible, even in the " neighbourhood of *Jupiter*, which otherwise " might be obscured by its overmuch light. " And though they may, in this case, be co- " loured, and *Jupiter*'s limb may appear dull; " yet when our only design is to observe the " moment of the loss, or recovery of their " light, we have no other concern, but to in- " crease that light as much as possible, that " they may become more certainly visible." Mr. *Hadley*'s words are these: *Philos. Transact.* N° 430. " I have been informed, that an " Object may be kept in view, without much " difficulty, even in pretty rough weather, " through a [refracting] Telescope magnify- " ing about ten times; which Telescopes sel- " dom comprehend an area of much more " than one degree in diameter; or at most " one degree, twenty minutes." [While I propose, even a Reflecting Telescope that will take one degree, and considerably above thirty minutes, or above three diameters of the Sun or Moon.]

## XXX.

*A Description of Mr.* Barston's *Quadrant.* See Fig. (7.)

This Quadrant is no other than one of the usual form, very exactly divided into degrees; whose Pendulum is considerably heavy, and is inclosed between two plains; in order to prevent all disorders from the wind. That Pendulum is connected to, and governs a train of

wheel-

wheel-work, within the quadrant; adjuſted nicely to the diviſion of the Inſtrument into *degrees*; and ſhewing, by its Index, without, the *minutes* belonging to theſe degrees. This train of wheel-work may be readily ſtop'd by the hand of the Obſerver, by means of a tricker, upon the firſt direction of its ſights to the Object: (which are at the diſtance of an intire diameter, and upon a ſemicircle.) By this Quadrant, the true altitude of the Sun, or Moon, or fixed Stars, or Planets, or Comets, may be, at any time, taken, both at Sea, and at Land, as has been frequently experienced, nearly to a ſingle minute. Which altitude of the heavenly Bodies is always the beſt way of finding the *Latitude* directly: as it is frequently the beſt way of finding the time at the Ship alſo: without which the *Longitude* itſelf cannot be diſcovered, either by Clocks, or by the Eclipſes, Occultations, and Conjunctions of *Jupiter*'s Planets; or by the Appulſes of the Moon to the fixed Stars, as all Aſtronomers do very well know. Nor indeed do I at all differ from Mr. *Witty*, or Mr. *Hodgſon*, in the value of ſuch an Inſtrument; when it is affirmed (Syſtem of the Mathematicks, Vol.I. *p.* 382, 383.) that "He "who can contrive any way to take the height "of any fixed Star at Sea, to a minute, or two, "may fairly be intituled to a ſhare of the diſ-"covery of the Longitude; and ought to have "a proportionable reward.

XXXI. A

XXXI.

*A Description of the other* Longitude Sector, *taken from Dr.* Halley's Zodiack.

This is only that Zodiack, as published by Mr. *Senex*, cut into three parts; and so pasted upon a Sector, like the former, as to exhibit, when opened, the intire Ecliptick, in one length. Its use is, by putting very small pins into the places of the Moon, at every noon, for a month, at the Meridian of *Greenwich*, from Mr. *Parker's*, or Mr. *Weaver's Ephemeris*, and stretching a fine silver thread along those pins, to trace the true course of the Moon, without Parallax, and as it would appear to an Eye from the Earth's center, among those fixed Stars that are inserted upon that Zodiack: and thereby to know those Stars which the Moon makes its transits over in such a position: and to determine, very nearly, the times of those Stars Immersions and Emersions in the same position at their Occultations by the Moon. Its use is also, upon proper allowance for the Parallax, to exhibit the same things to an Eye at the Earth's surface also. This method of using Dr. *Halley's* Zodiack will greatly improve the advantages to be reaped from it, in general: and, in particular, will supply the curious part of our seamen with a tolerable method for discovering the Longitude, during those six weeks, when *Jupiter* and his Planets are invisible. Of all which more fully hereafter.

 *N. B.* Since

*N.B.* Since both my Refracting and Reflecting Telescopes, especially the latter, enable us to see somewhat smaller fixed Stars, and Stars nearer the full Moon, than those used by Dr. *Halley*, and others on ship-board hitherto: It will be a desirable thing, that as many more of those smaller fixed Stars as can be now visible, may be observed and inserted into this Zodiack: that so the opportunities for discovering the Longitude this way may be more frequent, and advantageous to us. Tho' it must be confess'd, after all, that the opportunities of discovering the Longitude by *Jupiter*'s Planets, are much more frequent, the Calculations much more easy, and the Determations much more exact than those of the other.

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## XXXII.

*New Tables for the* Equation of Light: *fitted to Mr.* Bradley's *Astronomical Tables for* Jupiter's *first Planet, published in the* Philosophical Transactions, N° 361. *as well as to be republished at the end of Dr.* Halley's *own Astronomical Tables: where they are called the* second *and* third Equations.

*N. B.* The reason of the insertion of these New Tables for the Equation of Light is this; that since the publication of those Tables, which suppose this Equation to be but 7′, and its double 14′. Mr. *Bradley* has certainly discovered it to be no less than 8′ 13″, and doubled 16′ 26″. See *Philos. Transact.* N° 406.

*Secundæ Æquationes Conjunctionum Primi Satellitis cum Jove.*

| N. B Æq. | 0 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Æq. | Æq. | Æq. | Æq. | Æq. | Æq. | Æq. | Æq. | Æq. | Æq. |
| | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ | ′ ″ |
| 0 | 16 26 | 15 5 | 11 30 | 6 27 | 1 53 | 0 0 | 1 52 | 6 27 | 11 30 | 15 5 |
| 4 | 16 26 | 14 58 | 11 18 | 6 14 | 1 46 | 0 0 | 2 2 | 6 40 | 11 40 | 15 9 |
| 8 | 16 25 | 14 52 | 11 6 | 6 1 | 1 38 | 0 1 | 2 11 | 6 52 | 11 50 | 15 13 |
| 12 | 16 24 | 14 45 | 10 54 | 5 48 | 1 31 | 0 2 | 2 20 | 7 4 | 12 0 | 15 18 |
| 16 | 16 23 | 14 39 | 10 42 | 5 35 | 1 23 | 0 3 | 2 30 | 7 16 | 12 11 | 15 23 |
| 20 | 16 22 | 14 32 | 10 30 | 5 22 | 1 15 | 0 4 | 2 40 | 7 28 | 12 21 | 15 29 |
| 24 | 16 21 | 14 24 | 10 19 | 5 12 | 1 7 | 0 6 | 2 50 | 7 40 | 12 31 | 15 34 |
| 28 | 16 19 | 14 16 | 10 8 | 5 1 | 0 59 | 0 9 | 3 0 | 7 53 | 12 41 | 15 39 |
| 32 | 16 17 | 14 8 | 9 56 | 4 50 | 0 52 | 0 12 | 3 10 | 8 6 | 12 51 | 15 44 |
| 36 | 16 15 | 14 0 | 9 44 | 4 39 | 0 46 | 0 15 | 3 20 | 8 19 | 13 0 | 15 49 |
| 40 | 16 13 | 13 52 | 9 32 | 4 28 | 0 20 | 0 18 | 3 30 | 8 32 | 13 10 | 15 54 |
| 44 | 16 11 | 13 44 | 9 19 | 4 14 | 0 35 | 0 22 | 3 41 | 8 44 | 13 19 | 15 58 |
| 48 | 16 8 | 13 36 | 9 8 | 4 4 | 0 30 | 0 25 | 3 52 | 8 56 | 13 27 | 16 1 |
| 52 | 16 4 | 13 27 | 8 56 | 3 52 | 0 25 | 0 30 | 4 4 | 9 8 | 13 36 | 16 4 |
| 56 | 16 1 | 13 19 | 8 44 | 3 41 | 0 22 | 0 35 | 4 14 | 9 19 | 13 44 | 16 8 |
| 60 | 15 58 | 13 10 | 8 32 | 3 30 | 0 18 | 0 40 | 4 28 | 9 32 | 13 52 | 16 11 |
| 64 | 15 54 | 13 0 | 8 19 | 3 20 | 0 15 | 0 46 | 4 39 | 9 44 | 14 0 | 16 13 |
| 68 | 15 49 | 12 51 | 8 6 | 3 10 | 0 12 | 0 52 | 4 50 | 9 56 | 14 8 | 16 15 |
| 72 | 15 44 | 12 41 | 7 53 | 3 0 | 0 8 | 0 59 | 5 1 | 10 8 | 14 16 | 16 17 |
| 76 | 15 39 | 12 31 | 7 40 | 2 50 | 0 6 | 1 7 | 5 12 | 10 19 | 14 24 | 16 18 |
| 80 | 15 34 | 12 21 | 7 28 | 2 40 | 0 4 | 1 15 | 5 22 | 10 30 | 14 32 | 16 20 |
| 84 | 15 29 | 12 11 | 7 16 | 2 30 | 0 3 | 1 23 | 5 35 | 10 42 | 14 39 | 16 22 |
| 88 | 15 23 | 12 0 | 7 4 | 2 20 | 0 2 | 1 31 | 5 48 | 10 54 | 14 45 | 16 24 |
| 92 | 15 17 | 11 50 | 6 52 | 2 11 | 0 1 | 1 38 | 6 1 | 11 6 | 14 52 | 16 25 |
| 96 | 15 11 | 11 40 | 6 40 | 2 2 | 0 0 | 1 46 | 6 14 | 11 18 | 14 58 | 16 26 |
| 100 | 15 5 | 11 30 | 6 27 | 1 53 | 0 0 | 1 53 | 6 27 | 11 30 | 15 5 | 16 26 |

| *Tertiæ Æquationes Addendæ.* | | | |
|---|---|---|---|
| Num. A | Æquationes ′ | ″ | Num. A |
| 0 | 4 | 6 | 0 |
| 20 | 4 | 5 | 980 |
| 40 | 4 | 2 | 960 |
| 60 | 3 | 58 | 940 |
| 80 | 3 | 52 | 920 |
| 100 | 3 | 45 | 900 |
| 120 | 3 | 34 | 880 |
| 140 | 3 | 24 | 860 |
| 160 | 3 | 13 | 840 |
| 180 | 3 | 0 | 820 |
| 200 | 2 | 46 | 800 |
| 220 | 2 | 33 | 780 |
| 240 | 2 | 19 | 760 |
| 260 | 2 | 4 | 740 |
| 280 | 1 | 47 | 720 |
| 300 | 1 | 30 | 700 |
| 320 | 1 | 16 | 680 |
| 340 | 1 | 2 | 660 |
| 360 | 0 | 48 | 640 |
| 380 | 0 | 37 | 620 |
| 400 | 0 | 26 | 600 |
| 420 | 0 | 16 | 580 |
| 440 | 0 | 9 | 560 |
| 460 | 0 | 4 | 540 |
| 480 | 0 | 2 | 520 |
| 500 | 0 | 0 | 500 |

*N.B.* The firſt of theſe Tables properly ſuppoſes *Jupiter* and his Planets to be at their mean diſtances from the Sun and Earth; as they were at the end of the year 1731, and will be again before the end of 1743. But becauſe the *Eccentricity* of *Jupiter's* own Orbit is equal to *one quarter* of the Semidiameter of the Earth's Orbit; this requires another Table: becauſe that *Eccentricity* alters that Equation of Light one quarter as much as the other; or 2′, 3″, which quantity is therefore to be *added* at their greateſt diſtance in *Jupiter's* Aphelion; and *ſubſtracted* at their leaſt diſtance in *Jupiter's* Perihelion, which is provided for in this ſecond Table. However, in Mr. *Pound's* Method, all is done by Addition. Accordingly I have made the proper allowance for both their Epochas in each of theſe Tables; and do all by Addition alſo. Nor do we indeed properly ſtand in need of a diſtinct Table for this ſecond Equation of Light, as here and in the Tranſactions: becauſe the ſame number A is the

the Index for this, as well as for the first or principal Equation. And the addition of their Equations together in the Tables, would somewhat facilitate our calculations afterward.

*N. B.* The Eccentricity of the Earth's Orbit would itself also afford another correction of the Equation of Light. But this hardly ever amounting to a quarter of a minute in time; and being generally not near so much; neither Mr. *Pound*, Mr. *Bradley*, nor I have made any allowance for it.

## XXXIII.

### *Sir* Isaac Newton's *Table of Refraction.*

This is publiſhed by Dr. *Halley* in the *Philoſ. Tranſact.* N° 368. The great uſe of it will appear under the X^th^ Problem hereafter, when we come to find the true time at the Ship by the *apparent* altitude of the Sun, Moon, and Stars; which cannot be reduc'd to calculation, till, by the uſe of this, or the like Table, the *apparent* altitudes be reduced to the *real* ones, as will be exemplified hereafter.

*Tabula*

*Tabula Refractionum Siderum ad altitudines apparentes.*

| Al. ap. gra. | m. | Refract. m. | sec. | Al. ap. grad. | | Refract. m. | sec. | Al. ap. grad. | | Refract. | sec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 33 | 45 | 16 | 0 | 3 | 4 | 46 | 0 | 0 | 52 |
| 0 | 15 | 30 | 24 | 17 | 0 | 2 | 53 | 47 | 0 | 0 | 50 |
| 0 | 30 | 27 | 35 | 18 | 0 | 2 | 48 | 48 | 0 | 0 | 48 |
| 0 | 45 | 25 | 11 | 19 | 0 | 2 | 34 | 49 | 0 | 0 | 47 |
| 1 | 0 | 23 | 7 | 20 | 0 | 2 | 26 | 50 | 0 | 0 | 45 |
| 1 | 15 | 21 | 20 | 21 | 0 | 2 | 18 | 51 | 0 | 0 | 44 |
| 1 | 30 | 19 | 46 | 22 | 0 | 2 | 11 | 52 | 0 | 0 | 42 |
| 1 | 45 | 18 | 22 | 23 | 0 | 2 | 5 | 53 | 0 | 0 | 40 |
| 2 | 0 | 17 | 8 | 24 | 0 | 1 | 59 | 54 | 0 | 0 | 39 |
| 2 | 30 | 15 | 2 | 25 | 0 | 1 | 54 | 55 | 0 | 0 | 38 |
| 3 | 0 | 13 | 20 | 26 | 0 | 1 | 49 | 56 | 0 | 0 | 36 |
| 3 | 30 | 11 | 57 | 27 | 0 | 1 | 44 | 57 | 0 | 0 | 35 |
| 4 | 0 | 10 | 48 | 28 | 0 | 1 | 40 | 58 | 0 | 0 | 34 |
| 4 | 30 | 9 | 50 | 29 | 0 | 1 | 36 | 59 | 0 | 0 | 32 |
| 5 | 0 | 9 | 2 | 30 | 0 | 1 | 32 | 60 | 0 | 0 | 31 |
| 5 | 30 | 8 | 21 | 31 | 0 | 1 | 28 | 61 | 0 | 0 | 30 |
| 6 | 0 | 7 | 45 | 32 | 0 | 1 | 25 | 62 | 0 | 0 | 28 |
| 6 | 30 | 7 | 14 | 33 | 0 | 1 | 22 | 63 | 0 | 0 | 27 |
| 7 | 0 | 6 | 47 | 34 | 0 | 1 | 19 | 64 | 0 | 0 | 26 |
| 7 | 30 | 6 | 22 | 35 | 0 | 1 | 16 | 65 | 0 | 0 | 25 |
| 8 | 0 | 6 | 0 | 36 | 0 | 1 | 13 | 66 | 0 | 0 | 24 |
| 8 | 30 | 5 | 40 | 37 | 0 | 1 | 11 | 67 | 0 | 0 | 23 |
| 9 | 0 | 5 | 22 | 38 | 0 | 1 | 8 | 68 | 0 | 0 | 22 |
| 9 | 30 | 5 | 6 | 39 | 0 | 1 | 6 | 69 | 0 | 0 | 21 |
| 10 | 0 | 4 | 52 | 40 | 0 | 1 | 4 | 70 | 0 | 0 | 20 |
| 11 | 0 | 4 | 27 | 41 | 0 | 1 | 2 | 71 | 0 | 0 | 19 |
| 12 | 0 | 4 | 5 | 42 | 0 | 1 | 0 | 72 | 0 | 0 | 18 |
| 13 | 0 | 3 | 47 | 43 | 0 | 0 | 58 | 73 | 0 | 0 | 17 |
| 14 | 0 | 3 | 31 | 44 | 0 | 0 | 56 | 74 | 0 | 0 | 16 |
| 15 | 0 | 3 | 17 | 45 | 0 | 0 | 54 | 75 | 0 | 0 | 15 |

*N. B.* Becauſe in the diſcovery of the *Latitude* by Mr. *Barſton*'s Quadrant, the ſeamen will frequently want a Table of the Sun's *De-*

*clination*

*clination* at noon: And, because, in our present way of discovering the time at the Ship for the *Longitude*, we shall always want a Table of the Sun's *Right Ascension* for six in the evening: In the margin of my *Ephemeris* I have added both those Tables; and that for the Meridian of *Greenwich*: for which Meridian all my other Calculations are made also.

## XXXIV.

*A Table of the* Right Ascension, *both in degrees, and in time; and of the* Declination, *North, or South of fourteen of the principal fixed Stars; fitted to the year* 1740, *and serving for several years before, and after it: In order to the discovery of the time at the Ship, by Mr.* Barston's *Quadrant. Of which more hereafter.*

| | Right As. in deg. ° | ′ | Right As. in time. h | ′ | Declination. ° | ′ | |
|---|---|---|---|---|---|---|---|
| (1.) *Mencar*, in the Mouth of the Whale. | 42 | 14 | 2 | 49 | 3 | 2 | N. |
| (2.) *Aldebaran*, or Bulls Eye. | 65 | 16 | 4 | 21 | 15 | 58 | N. |
| (3.) *Orion*'s left foot, *Rigel.* | 75 | 38 | 5 | $2\frac{1}{2}$ | 8 | 32 | S. |
| (4.) In his right Shoulder. | 85 | 18 | 5 | 41 | 7 | 21 | N. |
| (5.) The Great Dog, *Syrius.* | 98 | 34 | 6 | 34 | 16 | 20 | S. |
| (6.) The Little Dog, *Procyon.* | 111 | 29 | 7 | 26 | 5 | 56 | N. |
| (7.) The Lyon's Heart, *Regulus.* | 148 | 39 | 9 | $54\frac{1}{2}$ | 13 | 16 | N. |
| (8.) The Lyon's Tail. | 174 | 0 | 11 | 36 | 16 | 15 | N. |
| (9.) The Virgin's Spike. | 197 | 55 | 13 | 12 | 9 | 45 | S. |
| (10.) *Arcturus.* | 211 | 4 | 14 | 4 | 20 | 40 | N. |
| (11.) Scorpion's Heart, *Antares.* | 243 | 19 | 16 | 13 | 25 | 45 | S. |
| (12.) Bright Star in the Eagle. | 294 | 34 | 19 | 38 | 8 | 12 | N. |
| (13.) Wing of *Pegasus*, *Marcab.* | 343 | 3 | 22 | 52 | 13 | 51 | N. |
| (14.) Head of *Andromeda.* | 358 | 47 | 23 | 55 | 27 | 48 | N. |

*N.B.* Some Stars of Southern Declination are here set down, for the use of Ships sailing beyond the Line. Otherwise those are not so useful on this side of it: as never coming to the east or west points of the Compass: near to which the best Observations for our present purpose are to be always made.

PRO-

## PROBLEMATA.

### I.

*To find the true time of the* Heliocentrick Oppositions *of* Jupiter'*s Planets, for the Meridian of* Greenwich.

This is to be done for the first Planet, by a Calculation from Mr. *Pound*'s Tables, published in the *Philosophical Transactions*, N° 361. but still as corrected by both the Equations for the velocity of the rays of light, mentioned under the XXXII^d^ *Lemma* foregoing. According to which rules I have myself made new Calculations for my *Ephemeris*, for the latter half of the year 1738.

For example. On *November* 2. 1737. the Heliocentrick Opposition of this first Planet is to be found by the method following.

| | d | h | ′ | ″ | A. | B. |
|---|---|---|---|---|---|---|
| I^st^ A.D. 1737. | 1 | 6 | 55 | 33 | 389 | 880 |
| *Novemb.* | 0 | 9 | 59 | 5 | 70 | 758 |
| | | | | | | 19 |
| Conjunct. Med. | 1 | 16 | 54 | 38 | 459 | |
| Equat I. | | | 28 | 33 | | 657 |
| II. | | | 4 | 18 | | |
| III. | | | | 4 | | |
| *Novemb.* | 1 | 17 | 27 | 33 = Mean time of ☍. | | |
| + Equation of Time | | | 15 | 12 | | |
| = | 1 | 17 | 42 | 45 = True time of ☍. | | |

For

For another example of this first Planet, on *November* 18th the same year, 1737.

| | d | h | ′ | ″ | A. | B. |
|---|---|---|---|---|---|---|
| Ist A.D. 1737. | 1 | 6 | 55 | 33 | 389 | 880 |
| *Novemb.* | 16 | 8 | 16 | 29 | 74 | 799 |
| | | | | | | 19 |
| Conj. Med. | 17 | 15 | 12 | 02 | 463 | |
| Equat I. | | | 29 | 44 | | 688 |
| II. | | | 6 | 21 | | |
| III. | | | | 4 | | |
| *Novemb.* | 17 | 15 | 48 | 11 | Mean time of ☌. | |
| + Equat Time | | | 10 | 58 | | |
| = | 17 | 15 | 59 | 9 | True time of ☌. | |

*Corollary.* If the *Semidurations* of the Planets in the total Shadow of *Jupiter* be *substracted* from, or *added* to these *Heliocentrick Oppositions*, they give us the true times of those their *Immersions* and *Emersions*: which we call their *Eclipses*. The former of which are alone visible from *Jupiter*'s *Conjunction* with the Sun, to his *Opposition*: and the latter from his *Opposition*, to his *Conjunction*. Examples of these Eclipses will be given presently.

*N.B.* In my *Ephemeris*, or Scheme of Configurations, I esteem each day to be a vulgar day, current; beginning at midnight, and ending at the midnight following; and adjust my numbers accordingly. So that the former 18 hours of it are supposed to be over at that six in the evening, to which I have fitted the Planets places; and the remaining 6 hours till XII o'-clock at night to belong to the same day. And, Note, that

to avoid the ambiguity of the same numbers of the hours, as II in the morning and II in the afternoon, V in the morning and V in the afternoon, *&c.* I imitate the rest of the Astronomers, and call the morning hours with them, as if the day began not at midnight, as in common use, but at the noon foregoing. Thus II in the morning is by the addition of XII called XIV, and V is called XVII, and so in all parallel cases. Which the Reader is ever to bear in mind in the use of these Calculations, and the *Ephemeris.*

*N. B.* No properly correct Astronomical Tables for the other three Planets being yet published; at least not in so easy a method as are those of Monf. *Cassini*'s for the first; we must find the time of the seconds coming to its Heliocentrick Opposition, by Mr. *Hodgson*'s annual Calculations of its Eclipses, out of Mr. *Flamsteed*'s Tables, corrected by himself, and inserted of late into the *Philosophical Transactions*, as well as we can: and either *substract*, or *add* their *semidurations*. Those Tables are fitted to the true time: and the Calculations for both the foregoing examples here follow:

| | d | h | ′ | |
|---|---|---|---|---|
| II[d] *Novemb.* | 2 | 3 | 7 | = true time of Emersion. |
| —Semiduration about | | 1 | $24\frac{1}{2}$ | |
| = | 2 | 1 | $42\frac{1}{2}$ | = true time of ☍. |
| For the second Example. | | | | |
| *Novemb.* | 16 | 8 | 8 | = true time of Emersion. |
| —Semiduration about | | 1 | $24\frac{1}{2}$ | |
| = | 16 | 6 | $53\frac{1}{2}$ | = true time of ☍. |

*N. B.* The III[d] and IV[th] Planets have here both their *Immersions* and *Emersions* set down by Mr. *Hodgson*: we may therefore, with greater

 assurance,

assurance, take the middle time between them for the true time of their *Heliocentrick Opposition:* (always here reckon'd from the Noon preceding) and proceed thus, in the first Example:

| | d | h | ′ | |
|---|---|---|---|---|
| III^d From *Octob.* | 28 | 10 | 50 | = true time of Emersion. |
| Take *Octob.* | 28 | 7 | 49 | = true time of Immers. |
| remains | 0 | 3 | 1 | |
| Whose half is | 0 | 1 | 30½ | |
| Add the second number | 28 | 7 | 49 | |
| Sum | 28 | 9 | 19½ | = true time of ☍. |

For the second Example.

| | | | | |
|---|---|---|---|---|
| From *Novemb.* | 11 | 18 | 51 | = true time of Emersion. |
| Take *Novemb.* | 11 | 15 | 52 | = true time of Immers. |
| remains | | 2 | 59 | |
| Whose half is | | 1 | 29½ | |
| Add the second number | 11 | 15 | 52 | = true time of ☍. |
| Sum | 11 | 17 | 21½ | |

| | | | | |
|---|---|---|---|---|
| IV^th From *Octob.* | 26 | 9 | 35 | = true time of Emersion. |
| Take *Octob.* | 26 | 7 | 12 | = true time of Immers. |
| remains | 0 | 2 | 23 | |
| Whose half is | 0 | 1 | 11½ | |
| Add the second number | 26 | 7 | 12 | |
| Sum | 26 | 8 | 23½ | = true time of ☍. |

For the second Example.

| | | | | |
|---|---|---|---|---|
| From *Novemb.* | 12 | 3 | 25 | = true time of Emersion. |
| Take *Novemb.* | 12 | 1 | 15 | = true time of Immers. |
| remains | 0 | 2 | 10 | |
| Whose half is | 0 | 1 | 5 | |
| Add the second number | 12 | 1 | 15 | |
| Sum | 12 | 2 | 20 | = true time of ☍. |

## II.

*To find the true Times of the* Geocentrick Opposition *of* Jupiter's *Planets, for the Meridian of* Greenwich.

This is to be done by substracting or adding the *Parallax of the Orb*, from, or to the true time

time of *Heliocentrick Oppoſition* already found; as follows,

In the firſt example, which only needs to be produced in ſo eaſy a caſe.

| | d | h | ′ | ″ | |
|---|---|---|---|---|---|
| Iſt *Novemb.* | 1 | 17 | 42 | 45 | = true time of Heliocentrick ☍. |
| Parallax Subſtract | 0 | 1 | 15 | 0 | |
| remains | 1 | 16 | 27 | 45 | = true time of Geocentrick ☍. |
| IId *Novemb.* | 2 | 1 | 42 | 30 | = true time of Heliocentrick ☍. |
| Parallax Subſtract | | 2 | 31 | 0 | |
| remains | 1 | 23 | 11 | 30 | = true time of Geocentrick ☍. |
| IIId *Octob.* | 28 | 9 | 19 | 30 | = true time of Heliocentrick ☍. |
| Parallax Subſtract | 0 | 5 | 6 | 0 | |
| remains | 28 | 4 | 13 | 30 | = true time of Geocentrick ☍. |
| IVth *Octob.* | 26 | 8 | 23 | 30 | = true time of Heliocentrick ☍. |
| Parallax Subſtract | 0 | 11 | 50 | 0 | |
| remains | 25 | 20 | 33 | 30 | = true time of Geocentrick ☍. |

*N. B.* If the *Geocentrick Oppoſition* be given, the *Heliocentrick* is eaſily found, by the reverſe of this practice: *i. e.* by *adding* the Parallax, inſtead of *ſubſtracting*: and by *ſubſtracting* it, inſtead of *adding*. This needs no farther examples.

## III.

*To find the* places *of any of theſe Planets at any given time.*

This is to be done by *ſubſtracting* the time of the *Geocentrick Oppoſition*, from the *time given.*

Thus we may find all their places on *November* 2d, at ſix in the evening, as follows: One example in each of the Planets will be ſufficient.

| | d | h | ′ | ″ | |
|---|---|---|---|---|---|
| Iſt From *Novemb.* | 2 | 6 | 0 | 0 | |
| Take *Novemb.* | 1 | 16 | 27 | 45 | = true ☍. |
| remains | | 13 | 32 | 15 | = true place. |

 IId From

| | d | h | ′ | ″ | |
|---|---|---|---|---|---|
| II^d From *Novemb.* | 2 | 6 | 0 | 0 | |
| Take | 1 | 23 | 11 | 30 | = true ☍. |
| remains | 0 | 6 | 48 | 30 | = true place. |
| III. From *Novemb.* | 2 | 6 | 0 | 0 | |
| Take *Octob.* | 28 | 4 | 13 | 30 | = true ☍. |
| remains | 5 | 1 | 46 | 30 | = true place. |
| IV^th From *Novemb.* | 2 | 6 | 0 | 0 | |
| Take *Octob.* | 25 | 20 | 33 | 30 | = true ☍. |
| remains | 7 | 9 | 26 | 30 | = true place. |

*N.B.* The time here and elsewhere given, is suppos'd to be at the Meridian of *Greenwich*: to which the Tables we make use of are fitted. But this time is not the same in other Meridians: because at 15, 30°, 45°, *&c.* eastward, this six a clock is 7, 8, 9 a clock, *&c.* As it is, but 5, 4, 3, *&c.* at Meridians as far westward. Which ought always to be borne in mind on such occasions.

## IV.

### *To find the* Eclipses, *or* Immersions *and* Emersions *of these Planets, with regard to the total shadow of* Jupiter.

This is to be done by substracting, and adding the *semidurations* of these Eclipses, from, or to their *Heliocentrick Opposition*; as follows,

The Mark for substractions and additions, is this: $\mp$.

| | | d | h | ′ | ″ | |
|---|---|---|---|---|---|---|
| I. *Novemb.* | | 1 | 17 | 42 | 45 | = true ☍. |
| | $\mp$ | 0 | 1 | 6 | 0 | = mean semiduration. |
| | = | 1 | 16 | 36 | 45 | = Immersion invisible. |
| | = | 1 | 18 | 48 | 45 | = Emersion visible. |
| II. *Novemb.* | | 2 | 1 | 42 | 30 | = true ☍. |
| | $\mp$ | 0 | 1 | 24 | 30 | = mean semiduration. |
| | = | 2 | 0 | 8 | 0 | = Immersion invisible. |
| | = | 2 | 3 | 7 | 0 | = Emersion visible. |

III. *Octob.*

| | | d | h | ' | '' | |
|---|---|---|---|---|---|---|
| III. *Octob.* | | 28 | 9 | 19 | 30 | = true ☍. |
| | ∓ | 0 | 1 | 46 | 0 | = mean semiduration. |
| | = | 28 | 7 | 33 | 30 | = Immersion visible. |
| | = | 28 | 11 | 5 | 30 | = Emersion visible. |
| IV. *Octob.* | | 26 | 8 | 23 | 30 | = true ☍. |
| | ∓ | 0 | 2 | 23 | 0 | = mean semiduration. |
| | = | 26 | 6 | 0 | 30 | = Immersion visible. |
| | = | 26 | 10 | 46 | 30 | = Emersion visible. |

*N. B.* These calculations suppose the Planets to pass either over the center of *Jupiter's* shadow, or very near it: as they do when they are not too remote from their Nodes. At other times these mean semidurations are too long; and the *Immersions* happen later, and the *Emersions* sooner than is here determined.

*N. B.* The former species of these Eclipses, or the *Immersions*, can be seen commonly for about 6 ½ months; from *Jupiter's* Conjunction with the Sun, to his Opposition. And the latter species of the same Eclipses, or the *Emersions*, for about 6 ½ months from his Opposition, to his Conjunction, I mean this, when the light of the Sun does not hinder us from seeing either these Planets, or even *Jupiter* himself: which is our unhappy case for about three weeks before, and as many after their Conjunctions with the Sun. Nor will the weeks immediately before, and after those six weeks afford many opportunities for observing them. Which opportunities yet will be more and more as the time before and after is farther distant from that *Conjunction*, and most numerous of all about their *Opposition*, as lasting then all the

the night long. *Jupiter*'s own situation has also a great hand in affording fewer, or more such opportunities. These being in southern signs fewer, and in northern signs more numerous. I mean this with regard to us who live in the northern Hemisphere. The reverse of which is true in the southern.

*N.B.* Since therefore *Jupiter* is now ascending from the southern to the northern signs; where he will continue near six years: those six years will peculiarly afford the Astronomers, Geographers, and Navigators of *Europe* the most frequent and valuable opportunities for perfecting the Theories of these Planets; and for making use of those Theories in their discovery of the Longitude, both at land and sea. Which I accordingly do earnestly recommend to them; and heartily wish they may not be neglected by them.

## V.

*To find the* Occultations, *or* Immersions, *and* Emersions *of these Planets, both beyond, and on this side the body of* Jupiter.

This is to be done by substracting, or adding the *semidurations* of these Planets, under this their obscurity, to their Geocentrick Oppositions or Conjunctions. Only the Reader must take notice, that the *Conjunctions* are easily found when the *Oppositions* are given: *viz.* by substracting, or adding half a Synodick period of each of these Planets from, or to the *Geocen-*

*trick*

*trick Oppoſitions.* One example in each Planet ſhall ſuffice here.

| | | d | h | ′ | ″ | |
|---|---|---|---|---|---|---|
| I[st] *Novemb.* | | 1 | 16 | 27 | 45 | = true ☍. |
| | ∓ | 0 | 1 | 9 | 0 | = Semiduration. |
| | = | 1 | 15 | 18 | 45 | = Im. inviſible. |
| | = | 1 | 17 | 36 | 45 | = Em. viſible. |
| + ½ Period to the firſt | | 0 | 21 | 14 | 18 | |
| | = | 2 | 13 | 42 | 3 | = true ☌. |
| | ∓ | | 1 | 9 | 0 | = Semiduration. |
| | = | 2 | 12 | 33 | 3 | = Im. inviſible. |
| | = | 2 | 13 | 42 | 3 | = Em. viſible. |
| II[d] *Novemb.* | | 1 | 23 | 13 | 0 | = true ☍. |
| | ∓ | 0 | 1 | 28 | 0 | = Semiduration. |
| | = | 1 | 21 | 45 | 0 | = Im. inviſible. |
| | = | 2 | 0 | 41 | 0 | = Em. viſible. |
| + ½ Period to the firſt | | 1 | 18 | 38 | 57 | |
| | = | 3 | 17 | 51 | 57 | = true ☌. |
| | ∓ | 0 | 1 | 28 | 0 | = Semiduration. |
| | = | 3 | 16 | 23 | 57 | = Im. viſible. |
| | = | 3 | 19 | 19 | 57 | = Em. viſible. |
| III[d] *Octob.* | | 28 | 4 | 13 | 30 | = true ☍. |
| | ∓ | 0 | 1 | 50 | 0 | = Semiduration. |
| | = | 28 | 2 | 23 | 30 | = Im. inviſible. |
| | = | 28 | 6 | 3 | 30 | = Em. viſible. |
| + ½ Period to the firſt | | 3 | 13 | 59 | 48 | |
| | = | 31 | 18 | 13 | 18 | = true ☌. |
| | ∓ | 0 | 1 | 50 | 0 | = Semiduration. |
| | = | 31 | 16 | 23 | 18 | = Im. viſible. |
| | = | 31 | 20 | 3 | 18 | = Em. viſible. |
| IV[th] *Octob.* | | 25 | 20 | 33 | 30 | = true ☍. |
| | ∓ | 0 | 2 | 27 | 0 | = Semiduration. |
| | = | 25 | 18 | 6 | 30 | = Im. inviſible. |
| | = | 25 | 23 | 0 | 30 | = Em. viſible. |
| + ½ Period to the firſt | | 8 | 9 | 2 | 36½ | |
| = *Novemb.* | | 3 | 5 | 36 | 6½ | = true ☌. |
| | ∓ | 0 | 2 | 27 | 0 | = Semiduration. |
| | = | 3 | 3 | 9 | 6½ | = Im. viſible. |
| | = | 3 | 8 | 3 | 6½ | = Em. viſible. |

VI. *To*

## VI.

### *To find the nearest Utmost Elongation of these Planets from the body of* Jupiter.

If the time given be that of the Geocentrick Opposition or Conjunction, the bare addition and substraction of one quarter of a Period gives the times of the two nearest *Utmost Elongations*, and needs no examples. But if, as usual, that time be any other, as that of six in the evening, the solution is thus:

Substract *one*, or *three* quarters of a Period from the given place; or the given place from *one*, or *three* quarters of a Period, the lesser number from the greater: the remains will be in the former case the first, and in the latter the second nearest Utmost Elongation. The use of the *Longitude Sector*, and of the *Scheme of Configurations* derived from it, will here prevent any mistakes; and will itself solve this Problem very nearly. However, take the following examples in numbers. Suppose that *November* $18^{h}$, 1737, at six in the evening, true time, the place of the $I^{ft}$ Planet has been found to be $0^{d}$, $15^{h}$, $19'$. Of the $II^{d}$, $2^{d}$, $1^{h}$, $43'\frac{1}{2}$. Of the $III^{d}$, $6^{d}$, $18^{h}$, $3'$, and of the $IV^{th}$, $6^{d}$, $16^{h}$, $35'$. It is required to find when they did severally come to their next *Utmost Elongation*. See *Lemma* $III^{d}$ before.

| | d | h | ′ |
|---|---|---|---|
| I. From $\frac{3}{4}$ of a Period | 1 | 7 | $51\frac{1}{2}$ |
| Take the place | 0 | 15 | 19 |
| remains | 0 | 16 | $32\frac{1}{2}$ after 6, or $10^{h}$, $32'\frac{1}{2}$ the next day. |

II. From

| | d | h | ′ | |
|---|---|---|---|---|
| II. From $\frac{3}{4}$ of a Period | 2 | 15 | $58\frac{1}{2}$ | |
| Take the place at 6 | 2 | 1 | 43 | |
| remains | 0 | 14 | $15\frac{1}{2}$ | after 6, or $8^h$, $15'\frac{1}{2}$ the next day. |
| III. From the place at 6 | 6 | 18 | 3 | |
| Take $\frac{3}{4}$ of a Period | 5 | 8 | $59\frac{2}{3}$ | |
| remains | 1 | 9 | $3\frac{1}{3}$ | before 6. |
| IV. From $\frac{3}{4}$ of a Period | 12 | 13 | 34 | |
| Take the place at 6 | 6 | 16 | 35 | |
| remains | 5 | 20 | 59 | after 6. |

See the Note after *Lemma* XXIV before.

## VII.

*To make a Table for every day of any month, or year,* &c. *of the* Geocentrick Places *of every one of these Planets at any time given: as here for six a clock in the evening; true, or common time.*

Take the examples following: which are no other than consequences of the III Problem foregoing: and are obtained by addition of equal days motions, till they amount to more than a Period: when that Period is to be substracted, and the remainder still solves the Problem.

| I. | | d | h | ′ | ″ | |
|---|---|---|---|---|---|---|
| *Novemb.* 18 at 6 gives us | | 0 | 15 | 18 | 44 | |
| 19 - - - | | 1 | 15 | 18 | 44 | |
| 20 - - - | | 2 | 15 | 18 | 44 | |
| | — | 1 | 18 | 28 | 36 | |
| | = | 0 | 20 | 50 | 8 | |
| 21 - - - | | 1 | 20 | 50 | 8 | |
| | — | 1 | 18 | 28 | 36 | |
| | = | 0 | 2 | 21 | 32 | |
| 22 - - - | | 1 | 2 | 21 | 32 | &c. |

II.

| | | | d | h | ′ | ″ | |
|---|---|---|---|---|---|---|---|
| *Novemb.* | 18 | at 6 gives us | 2 | 1 | 43 | 30 | |
| | 19 | - - - | 3 | 1 | 43 | 30 | |
| | 20 | - - - | 4 | 1 | 43 | 30 | |
| | | — | 3 | 13 | 17 | 54 | |
| | | = | 0 | 12 | 25 | 36 | |
| | 21 | - - - | 1 | 12 | 25 | 36 | |
| | 22 | - - - | 2 | 12 | 25 | 36 | |
| | 23 | - - - | 3 | 12 | 25 | 36 | |
| | 24 | - - - | 4 | 12 | 25 | 36 | |
| | | — | 3 | 13 | 17 | 54 | |
| | | = | 0 | 23 | 7 | 42 | |
| | 25 | - - - | 1 | 23 | 7 | 42 | &c. |

III.

| | | | | | | |
|---|---|---|---|---|---|---|
| *Novemb.* | 18 | at 6 gives us | 6 | 18 | 3 | |
| | 19 | - - - | 7 | 18 | 3 | |
| | | — | 7 | 4 | 0 | |
| | | = | 0 | 14 | 3 | |
| | 20 | - - - | 1 | 14 | 3 | |
| | 21 | - - - | 2 | 14 | 3 | |
| | 22 | - - - | 3 | 14 | 3 | |
| | 23 | - - - | 4 | 14 | 3 | |
| | 24 | - - - | 5 | 14 | 3 | |
| | 25 | - - - | 6 | 14 | 3 | |
| | 26 | - - - | 7 | 14 | 3 | |
| | | — | 7 | 4 | 0 | |
| | | = | 0 | 10 | 3 | |
| | 27 | - - - | 1 | 10 | 3 | &c. |

IV. *No-*

| | | d | h | ′ |
|---|---|---|---|---|
| IV. | | | | |
| *Novemb.* | 18 at 6 gives us | 6 | 16 | 35 |
| | 19 - - - | 7 | 16 | 35 |
| | 20 - - - | 8 | 16 | 35 |
| | 21 - - - | 9 | 16 | 35 |
| | 22 - - - | 10 | 16 | 35 |
| | 23 - - - | 11 | 16 | 35 |
| | 24 - - - | 12 | 16 | 35 |
| | 25 - - - | 13 | 16 | 35 |
| | 26 - - - | 14 | 16 | 35 |
| | 27 - - - | 15 | 16 | 35 |
| | 28 - - - | 16 | 16 | 35 |
| | 29 - - - | 17 | 16 | 35 |
| | — | 16 | 18 | 5 |
| | = | 0 | 22 | 30 |
| | 30 - - - | 1 | 22 | 30 &c. |

*N. B.* This Table is thus far made from the mean motions of theſe Planets only; without the allowance for any Equations ariſing from the difference of the Parallax of the Orb; or from the ſucceſſive motion of Light, or from the inequality of *Jupiter*'s own motion: which yet ought to be allow'd for in the Aſtronomical Calculations of theſe Planets, and is allow'd for in the Iſt, IId, and IIId, in the large Table of thoſe places made for the Longitude Sector: (a ſpecimen of which ſhall be ſet down preſently.) If therefore we at any time proceed in this way, we muſt frequently make new Calculations. Otherwiſe we ſhall ſoon err, and that very conſiderably alſo.

*N.B.* The Reader is to be farther informed, that in this Specimen for the latter half of 1738. I have had uſe of Mr *Hodgſon*'s Calculations of the Eclipſes of the ſecond and third, as they ſtand in the *Philoſophical Tranſactions* for this year, N° 443. Yet have I made thoſe of the I[st] myſelf, and compared them with both his, and Mr *Weaver*'s Calculations; and hope they will nearly correſpond to the Obſervations. But the fourth Planet having no Eclipſes, neither in this nor the following year, the calculations and places of that Planet in my *Ephemeris* muſt needs, at preſent, be very groſs. However, I hope, againſt the next year, to procure ſuch helps as will enable me to place that Planet much more exactly.

A Table

A Table of the places of *Jupiter*'s Planets, as seen from the Earth, for the latter end of *November*, and for *December* 1737, at six a Clock in the evening, true time.

| | I. | | | II. | | | III. | | | IV. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nov. | d | h | ′ | d | h | ′ | d | h | ′ | d | h | ′ |
| 18 | 0 | 15 | 19 | 2 | 1 | 43½ | 6 | 18 | 3 | 6 | 16 | 35 |
| 19 | 1 | 15 | 19 | 3 | 1 | 43½ | 0 | 14 | 3 | 7 | 16 | 34 |
| 20 | 0 | 20 | 50 | 0 | 12 | 25 | 1 | 14 | 3 | 8 | 16 | 31 |
| 21 | 0 | 2 | 21½ | 1 | 12 | 25 | 2 | 14 | 3 | 9 | 16 | 29 |
| 22 | 1 | 2 | 21½ | 2 | 12 | 25 | 3 | 14 | 3 | 10 | 16 | 28 |
| 23 | 0 | 7 | 52 | 3 | 12 | 27 | 4 | 14 | 3 | 11 | 16 | 26 |
| 24 | 1 | 7 | 52 | 0 | 23 | 10 | 5 | 14 | 3 | 12 | 16 | 25 |
| 25 | 0 | 13 | 23 | 1 | 23 | 10 | 6 | 14 | 3 | 13 | 16 | 23 |
| 26 | 1 | 13 | 23 | 2 | 23 | 10 | 0 | 10 | 4 | 14 | 16 | 22 |
| 27 | 0 | 18 | 54 | 0 | 9 | 52 | 1 | 10 | 4 | 15 | 16 | 20 |
| 28 | 0 | 0 | 25 | 1 | 9 | 52 | 2 | 10 | 4 | 16 | 16 | 19 |
| 29 | 1 | 0 | 25 | 2 | 9 | 52 | 3 | 10 | 4 | 0 | 22 | 12 |
| 30 | 0 | 5 | 56 | 3 | 9 | 52 | 4 | 10 | 4 | 1 | 22 | 11 |
| Dec. 1 | 1 | 5 | 55 | 0 | 20 | 35 | 5 | 10 | 5 | 2 | 22 | 9 |
| 2 | 0 | 11 | 27 | 1 | 20 | 35 | 6 | 10 | 5 | 3 | 22 | 7 |
| 3 | 1 | 11 | 26 | 2 | 20 | 35 | 0 | 6 | 5 | 4 | 22 | 5 |
| 4 | 0 | 16 | 58 | 0 | 7 | 18 | 1 | 6 | 5 | 5 | 22 | 2 |
| 5 | 1 | 16 | 59 | 1 | 7 | 19 | 2 | 6 | 6 | 6 | 22 | 0 |
| 6 | 0 | 22 | 31 | 2 | 7 | 20 | 3 | 6 | 7 | 7 | 21 | 54 |
| 7 | 0 | 4 | 4 | 3 | 7 | 21 | 4 | 6 | 7 | 8 | 21 | 48 |
| 8 | 1 | 4 | 5 | 0 | 18 | 4 | 5 | 6 | 8 | 9 | 21 | 42 |
| 9 | 0 | 9 | 37 | 1 | 18 | 5 | 6 | 6 | 8 | 10 | 21 | 36 |
| 10 | 1 | 9 | 37 | 2 | 18 | 6 | 0 | 2 | 9 | 11 | 21 | 30 |
| 11 | 0 | 15 | 10 | 0 | 4 | 49 | 1 | 2 | 9 | 12 | 21 | 24 |
| 12 | 1 | 15 | 11 | 1 | 4 | 50 | 2 | 2 | 10 | 13 | 21 | 18 |
| 13 | 0 | 20 | 44 | 2 | 4 | 51 | 3 | 2 | 10 | 14 | 21 | 12 |
| 14 | 0 | 2 | 17 | 3 | 4 | 52 | 4 | 2 | 11 | 15 | 21 | 6 |
| 15 | 1 | 2 | 17 | 0 | 15 | 33 | 5 | 2 | 11 | 0 | 2 | 54 |
| 16 | 0 | 7 | 49 | 1 | 15 | 34 | 6 | 2 | 12 | 1 | 2 | 48 |
| 17 | 1 | 7 | 48 | 2 | 15 | 34 | 7 | 2 | 12 | 2 | 2 | 42 |
| 18 | 0 | 13 | 19 | 0 | 2 | 16 | 0 | 22 | 9 | 3 | 2 | 36 |
| 19 | 1 | 13 | 18 | 1 | 2 | 16 | 1 | 22 | 5 | 4 | 2 | 30 |
| 20 | 0 | 18 | 49 | 2 | 2 | 17 | 2 | 22 | 0 | 5 | 2 | 24 |
| 21 | 0 | 0 | 20 | 3 | 2 | 17 | 3 | 21 | 57 | 6 | 2 | 18 |
| 22 | 1 | 0 | 18 | 0 | 12 | 59 | 4 | 21 | 53 | 7 | 2 | 12 |
| 23 | 0 | 5 | 48 | 1 | 12 | 59 | 5 | 21 | 50 | 8 | 2 | 6 |
| 24 | 1 | 5 | 48 | 2 | 13 | 0 | 6 | 21 | 47 | 9 | 2 | 0 |
| 25 | 0 | 11 | 20 | 3 | 13 | 0 | 0 | 17 | 42 | 10 | 1 | 54 |
| 26 | [illegible] | 11 | 20 | 0 | 23 | 24 | 1 | 17 | 37 | 11 | 1 | 48 |
| 27 | 0 | 16 | 50 | 1 | 23 | 24 | 2 | 17 | 34 | 12 | 1 | 42 |
| 28 | 1 | 16 | 49 | 2 | 23 | 24 | 3 | 17 | 30 | 13 | 1 | 36 |
| 29 | 0 | 22 | 21 | 0 | 10 | 6 | 4 | 17 | 26 | 14 | 1 | 30 |
| 30 | 0 | 3 | 52 | 1 | 10 | 6 | 5 | 17 | 22 | 15 | 1 | 24 |
| 31 | 1 | 3 | 5 | 2 | 10 | 6 | 6 | 17 | 18 | 16 | 1 | 20 |

## VIII.

*To find the places of these Planets by the* Longitude Sector, *at any given time, at the Meridian of* Greenwich.

Take this Sector, and lay it open before you. Then take four common pins, of the larger sort, and place them, by such a Table as has been just now exemplified, at their several places, for 6 a clock in the evening, on the day you propose to know those places. Remove each pin along its own Orbit, as many hours and minutes as the time given is different from 6 a clock: *backward*, if that time be *before* 6 and *forward*, if it be *after* 6. Then will the four pins, representing these four Planets, stand true, and rightly determine their places at the time given.

Thus if it be required to find the places of these Planets by the *Longitude Sector* at 7 a clock at night, the 18th of *November*, and the 31st of *December*, 1737. [the former being the day when the Moon came very near to *Jupiter*: and the latter the day when there were four Conjunctions of *Jupiter*'s Planets in a few hours time.] In the first place, write down their places at 6 a clock on both those days, out of the foregoing Table, which are these.

*Nov*. 18.

| | | d | h | ′ | | | d | h | ′ |
|---|---|---|---|---|---|---|---|---|---|
| *Nov.* 18. | I. | 0 | 15 | 19 | *Dec.* 31. | I. | 1 | 3 | 51 |
| | II. | 2 | 1 | 43 ⅓ | | II. | 2 | 10 | 6 |
| | III. | 6 | 18 | 3 | | III. | 6 | 17 | 18 |
| | IV. | 6 | 16 | 35 | | IV. | 16 | 1 | 20 |

Then ſet thoſe four large pins in theſe their ſeveral places, at 6 a clock, which will then exhibit theſe Planets ſtanding two over againſt your right hand, or weſtward, and two over againſt your left hand, or eaſtward, from the body of *Jupiter*, upon *Nov.* 18. but all over againſt your right hand, or weſtward, upon *Dec.* 31. and will have the following diſtances from *Jupiter*'s center, in inches, and decimals of an inch.

| | | inch. | | | inch. |
|---|---|---|---|---|---|
| *Nov.* 18. | I. | 12,3 | *Dec.* 31. | I. | 13,7 |
| | II. | 12,5 | | II. | 23,2 |
| | III. | 14,5 | | III. | 15,6 |
| | IV. | 42,8 | | IV. | 18,5 |

And thus are they to be truly repreſented in miniature at 6, in a Scheme of *Configurations*, ſuch as I have by me for thoſe months. Then remove each pin one hour forward, for 7 a clock, the time requir'd; when they will ſtand thus.

| | | inch. | | | inch. |
|---|---|---|---|---|---|
| *Nov.* 18. | I. | 10,5 | *Dec.* 31. | I. | 15,1 |
| | II. | 14,2 | | II. | 24,0 |
| | III. | 13,2 | | III. | 13,3 |
| | IV. | 42,0 | | IV. | 17,5 |

*Corollary*

*Corollary* (1.) If you desire to know farther when any of these Planets will come to an *Occultation* by the body of *Jupiter*, from which it is not too remote, remove its pin forwards, from its place at 6 a clock, till it cross one of the tangents of *Jupiter*, and observe how many hours and minutes you have removed it. That interval, as before, added to 6 a clock, gives you the time of such *Occultation*. Thus if we take the foregoing examples, we shall soon see, both on the Sector more exactly, and on a Scheme of Configurations nearly, that in the former example the II[d] and IV[th] are, the one going away from *Jupiter*, and the other too remote from him: and that in the second example the I[st] and II[d] are going away from *Jupiter*; and in the second, the III[d] and IV[th] are going towards *Jupiter*, and will not be very long ere they come to him: And by removing the several pins, that represent their places at 6 a clock, those two evenings will cross the nearest tangent of *Jupiter*, and will afford *Immersions*, by being removed forward.

| | | | h | ′ | | | | h | ′ |
|---|---|---|---|---|---|---|---|---|---|
| *Nov.* | 18. | I. | 4 | $47\frac{1}{2}$. | *Dec* | 31. | III. | 8 | 50 |
| | | III. | 8 | 7. | | | IV. | 14 | 10 |

As also that they will cross the second Tangent, and afford *Emersions*, by being removed one intire duration of such Occultations farther, *viz.*

*Nov.*

| | | | | | | |
|---|---|---|---|---|---|---|
| | | h ′ | | | | h ′ |
| *Nov.* 18. | I. | 2 . 18. | | *Dec.* 31. | III. | 3 . 40. |
| | III. | 3 . 40. | | | IV. | 4 . 54. |

Which are therefore very near the true times of ſuch *Occultations*, of ſuch *Immerſions* and *Emerſions* reſpectively, *i. e.* upon the ſuppoſition that theſe Planets were then near their Nodes, but not otherwiſe; as has been already obſerved under the V$^{th}$ Lemma foregoing.

*Coroll.* (2.) If you deſire to know when any of theſe Planets will come to one of its *Utmoſt Elongations*, that is not too remote, remove its pin to ſuch Elongation; and take notice, as before, how many hours and minutes you have removed it forward, or backward. That interval, as before, added to, or ſubſtracted from 6 a clock, gives you nearly the true time of ſuch Elongation. Only it muſt be noted, that the Sines near ſuch *Utmoſt Elongation* differ little from one another; and that therefore ſuch time cannot be determined by the Sector to any exactneſs. In that caſe the former method by numbers, as under Problem VI. before, anſwers this enquiry with much greater accuracy. However, to go on with the ſecond example: (the other affording us no ſuch Elongation near.) If we remove the pins repreſenting the I$^{ſt}$ and II$^{d}$ Planet forward from 6 a clock, the hours and minutes following, they will then be each of them very near their utmoſt Elongations.

N Dec.

| | | h | ′ |
|---|---|---|---|
| *Dec.* 31. | I. | 4 | 0. |
| | II. | 5 | 24. |

*Coroll.* (3.) If you deſire to know when any two of theſe Planets, which are not at 6 a clock very remote from each other, have met, or will meet one another, to our eye, and be in *Conjunction*; you muſt remove each pin that repreſents any ſuch two of them, forward, or backward, till you ſee them at an equal diſtance from the center of *Jupiter*, and in the ſame croſs perpendicular. That interval, added to or ſubſtracted from the hour of 6, gives you the true time: and this, when the Planets Theories ſhall be perfected, to great exactneſs alſo.

Thus if we now make uſe of the red lines, and the larger ſcale, we ſhall find that by removing, in the firſt example, the II$^{d}$ and III$^{d}$ forward; and in the ſecond, by removing the II$^{d}$ and III$^{d}$, the II$^{d}$ and IV$^{th}$ backwards: as alſo by removing the I$^{ſt}$ and III$^{d}$ and the I$^{ſt}$ and IV$^{th}$ forward, as far as to bring them to their *Conjunctions* reſpectively, thoſe *Conjunctions* will be found thus,

*Nov.* 18. ☌ II$^{d}$ and III$^{d}$ at 6$^{h}$. 38′. or ſomewhat before the approach of the moon to *Jupiter*.

| | | h | ′ | |
|---|---|---|---|---|
| *Dec.* 31. | ☌ II$^{d}$ and III$^{d}$ at | 2 | 46 | before Sun-ſet. |
| | ☌ II$^{d}$ and IV$^{th}$ at | 3 | 42 | |
| | ☌ I$^{ſt}$ and II.$^{d}$ at | 6 | 39 | after Sun ſet. |
| | ☌ I$^{ſt}$ and IV$^{th}$ at | 8 | 20 | |

In

In which latter example, the laſt day of the old year, there was ſuch a cluſter of theſe Planets, and number of *Conjunctions* together, as very rarely happens; the two latter of which, as well as the firſt on *Nov.* 18th, were viſible, and were accordingly well obſerved at Mr. *Lynn*'s at *Southwick*, *Northamptonſhire*, and at Mr. *Barker*'s at *Lyndon*, *Rutland*.

*N. B.* It muſt be here farther remark'd, that this branch of the Problem before us is of the greateſt conſequence to my preſent deſign; and that it cannot, without great difficulty, be ſolved by numbers, as the other may; and this by reaſon of the continual inequality of theſe apparent motions, and the four different ſemidiameters to which the Sines, Hours, and Minutes are to be accommodated. While the *Longitude Sector* ſolves it with the greateſt eaſe, accuracy, and ſatisfaction.

## IX.

*To compoſe a Scheme of the* Configurations *of theſe four Planets, for any number of months, for an intire year; or for any number of years required, by the uſe of the* Longitude Sector.

This is the principal and highly valuable uſe of this Sector, and what will render the diſcovery of the exact times when the ſeveral *Occultations* and *Conjunctions* of theſe Planets are to be both computed and obſerved, for the diſcovery of the *Longitude*, very eaſy, very cheap, and very familiar.

In order to the obtaining which advantages, you must proceed as follows.

Place the Sector open before you. Then set the four pins, representing the four Planets, in their proper places, according to such a Table as has been already exemplify'd under Problem VII. before, for six in the evening. Lay a rule perpendicularly across the four double lines, drawn upon the Sector, for the Orbits of these Planets, distinctly, at each of those pins: Look upon the divisions near both the edges of the Sector, and note how many inches and decimals of an inch each of those pins is from the Center or Axis of the Sector, and whether to the right hand, or to the left. Take with your compasses either $\frac{1}{10}$, or $\frac{1}{15}$, or $\frac{1}{20}$ of those inches and decimals, and set one of its points upon your paper, (already ruled, and prepared for the daily insertion of these Configuration) from the Center, or Axis to the right hand, or to the left, as the pins on your Sector do direct you. The other point will determine the true place of the Planet concern'd, that evening at 6 a clock. Do this distinctly for every pin or Planet, and for every day of the year that *Jupiter* is visible. You will then have before you a true representation of the situation of every one of *Jupiter*'s Planets, at that time of the evening, for every day of the year, at the meridian of *Greenwich*.

*Corollary.* If all these pins be once removed to the hour and minute when any of them come to either of the Tangents of *Jupiter*, for

for *Occultations*; or to its greateſt diſtance from the center for *Utmoſt Elongations*; or to the place of their mutual meetings, for their *Conjunctions*, as already directed; and the intervals of time for ſuch removals be noted; you will have the ſituation of all theſe Planets at the times of ſuch *Occultation*, *Utmoſt Elongation*, or *Conjunction*. And if the $\frac{1}{10}$, or $\frac{1}{15}$, or $\frac{1}{20}$ of ſuch removals be imitated on ſuch a Paper of *Configurations*, the paper will then repreſent, in miniature, the ſame ſituations alſo.

*N. B.* I have noted in my Scheme of theſe Configurations, not only thoſe Eclipſes that are any where viſible, with the true place, at 6 a clock, but the preſent *direction* of each Planet, at that time, by a very ſmall line, imitating the point of an arrow, drawn from the very ſmall circle that ſtands for ſuch a Planet. This is a circumſtance of no ſmall advantage, tho' commonly omitted in the like Schemes of their Eclipſes hitherto.

*N. B.* I need not here inform my Aſtronomical Readers, that when that ſmall line points *eaſtward*, the Planet thereby repreſented, and denominated by its number 1, 2, 3, and 4, is *beyond* Jupiter; and when it points weſtward, it is *on this ſide* of him. Nor need I inform him that moſt of thoſe Teleſcopes, by which we view theſe Planets, contradict my own, and nature's repreſentation, by *inverting* all their objects; and exhibiting what is really on the *left*

*left* hand of *Jupiter*, as on his right: and what is *beneath* the center of *Jupiter*, as *above* it, and *vice versa*. But all Observers of the Heavens by Telescopes are so perpetually used to this inversion, and make such constant allowance for it, that I need add no more about it in this place.

## X.

*To find the Longitude of a Ship at Sea, by any of the* Eclipses, Occultations, *or* Conjunctions *of* Jupiter's *Planets, observed there.*

To solve this GRAND PROBLEM, which is the main design of the former *Lemmata* and *Problemata*, let some skilful Observer, who has a sharp eye and dextrous hands, take either the refracting or reflecting Telescope, already described, and observe by one of them, either an *Eclipse*, or *Occultation*, or *Conjunction*, (which will almost always be one of those noted in my Scheme of *Configurations*, and whose time, in all Meridians, may be near enough guess'd at by the Scheme, to forewarn Observers to expect them:) And let this be done with all possible accuracy. At the very same moment of time, as near as possible, let some other like Observer take, by Mr. *Barston*'s Quadrant, or otherwise, the altitude of some one of those 14 bright Stars noted in the Table under Lemma XXXIV foregoing. Then, by the Rules to be set down presently, find the hour and minute at the Ship, and this also to the greatest nicety possible. Compare the hour and minute for that *Eclipse*,

*Eclipſe*, *Occultation*, or *Conjunction* in the ſcheme of Configurations, with the hour, and minute at the ſhip; the *difference* between that time in the ſcheme, and the time by obſervation, gives you the *difference* in time between the meridian of *Greenwich*, and the meridian of the Ship at the time of the obſervations; which *difference* is no other than the *Longitude* of *Greenwich*, to which the time of the Configurations is accommodated, from the *Longitude* of the Ship, whereon the Obſervations are made. And, by allowing 15 degrees to an hour, gives you the ſame *Longitude* in degrees and minutes of the Equinoctial alſo.

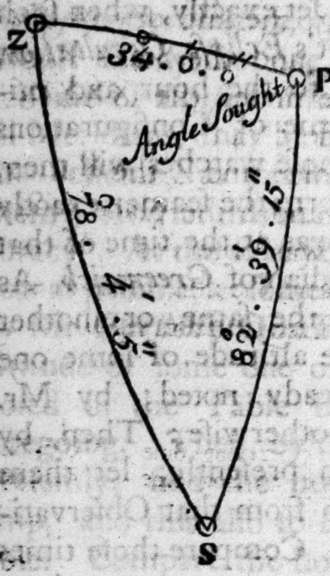
*N. B.* If ſuch *Eclipſe*, or *Occultation*, or *Conjunction* of *Jupiter*'s Planets cannot be conveniently obſerv'd at the very ſame time with the altitude of the Star, let ſome of the watches on ſhipboard be ſet exactly, when ſuch Obſervation of the Planet's *Eclipſe*, *Occultation*, or *Conjunction* is made, to the hour and minute noted in the ſcheme of Configurations for that appearance. Thoſe watches will then, for an hour, or more, inform the ſeamen exactly enough what a clock it was at the time of that Obſervation by the Meridian of *Greenwich*. As ſoon as this is done, let the ſame, or another ſkilful Obſerver take the altitude of ſome one of thoſe 14 Stars, already noted, by Mr. *Barſton*'s Quadrant, or otherwiſe: Then, by the rules to be ſet down preſently, let them find the time of the Ship from that Obſervation, as exactly as may be. Compare thoſe times

together;

together; I mean that at *Greenwich*, shewn by the watch; and that at the Ship, shewn by the calculation from the Star's altitude, and this exactly at the taking of that altitude. The *difference* of those times is the *Longitude of the Ship from* Greenwich *at that time.* And Note, that the *later* hours and minutes shew meridians more *easterly*, and the earlier more *westerly*, than the meridian of *Greenwich.*

Now the Calculation of the time of the Ship from the Star's altitude is to be thus made.

Let us suppose that the bright Star in the right shoulder of *Orion* was observed *December* 31st, 1737. in the evening, on shipboard, in the *Latitude* of 56° north, to be not far off the east point of the compass, and just 12° high above the Horizon. And this at the very same time that a *Conjunction* of *Jupiter's* Ist and IIId Planet was seen also, it is required to find the time at the Ship at that *Conjunction.* The refraction by the air at this altitude of 12° from Sir *Isaac Newton's* Table already set down under Lemma XXXIII. foregoing is 4′. 5″. which is to be substracted from the apparent altitude



altitude of 12°. The remainder is 11° 55′ 55″, and is the real altitude of the Star at the time of its Observation. Now in order to discover the true or common time at the Ship from these *data*, we must resolve the foregoing oblique angled spherical Triangle, whose three sides are given, I mean the distance between the Pole of the World and the vertex or zenith; which is equal to the complement of the Latitude = 34°, the complement of the Star's north Declination from the Equinoctial = 82° 39′ 15″, and the Star's distance from the vertex or zenith; which is equal to the complement of its altitude = 78° 4′ 5″ by which the Angle ZPS, which the Star makes with the meridian, is to be discovered. This requires the following process. Noting withal, that it appears by the proper Tables, that the Sun's Right Ascension was, at 6 in the evening, the last day of *December*, in time 19ʰ 23′, and the Star's Right Ascension, by the Table under the XXXIVᵗʰ Lemma foregoing in time 5ʰ 41′.

Let P be the North Pole: and Z the Vertex, or Zenith of the Ship: and S the place of the Star, when its altitude was observed. Where ZS is the *base*, and ZP and PS the *sides*, including the angle sought. The numbers will stand thus:

| | | ° | ′ | ″ | | | |
|---|---|---|---|---|---|---|---|
| ZS the base | = | 78 | 4 | 5 | | | |
| PS a side | = | 82 | 39 | 15 | = | Log. Sine | 9,99642 |
| PZ the other side | = | 34 | 0 | 0 | = | Log. Sine | 9,74756 |

| | ° | ′ | ″ | | | |
|---|---|---|---|---|---|---|
| Sum of all three | =194 | 43 | 20 | | = | 19,74398 |
| The half Sum | = 97 | 21 | 40 | | | |
| (Its supplement | 82 | 38 | 20) | Log. Sine | = | 9,99642 |
| Difference of ZS, and the half Sum } | 19 | 17 | 35 | Log. Sine | = | 9,51903 |
| Log. of the Radius doubled | | | | | = | 20,00000 |
| Sum of the last three numbers | | | | | = | 39,51545 |
| Remainder, or difference of the former Sum, and this: | | | | | | 19,77147 |
| Half that remainder: | | | | | = | 9,88573 |
| | | | | = Cosine of | 39° | 46′ |
| Its double is ZPS the angle sought | | | | | = 79 | 32 |
| Which in time corresponds to | | | | | = $5^h$ | 18′ |
| The Stars Right Ascension was in time | | | | | = 5 | 41 |
| Add to it 24 hours, the Sum is, in time | | | | | = 29 | 41 |
| Take out of it the Sun's Right Ascension | | | | | = 19 | 23 |
| Remainder | | | | | = 10 | 18 |
| From which substract the time, that answers to the angle now found } | | | | | = 5 | 18 |
| The remainder is the time at the Ship | | | | | = 5 | 0 |

Which $5^h$ is, in the last place, to be substracted from the time at *Greenwich*: which, by the Scheme of Configurations, was $6^h$ 39′. The Difference or Remainder is $1^h$ 39′, and is no other than the Longitude of the Ship from *Greenwich* in time; or in degrees 24° 45′ Westward.

*N.B.* You are only then to add $24^h$, or a whole circle, to the Stars Right Ascension, when it is *lesser* than that of the Sun. But remember that when the Star is observed near the *West* point of the Compass, you must not *substract*, but *add* the Suns and the Stars Right Ascensions together, in order to gain the time at the Ship. As also it must be noted, that this

this time is not the mean or equal, but the true or common time.

But because this Problem is of such great importance in the discovery of the Longitude, I shall produce another method of trigonometrical calculation: that by its agreement, the former calculation may be confirm'd, and that both of them may be still made use of at Sea upon all occasions; to prevent any possibility of error therein. The Process will stand thus;

| | | ° | ′ | ″ |
|---|---|---|---|---|
| Complement of the altitude ZS | = | 78 | 4 | 5 |
| Complement of the Declination PS | = | 82 | 39 | 15 |
| Complement of the Latitude | = | 34 | 0 | 0 |
| Sum of those three sides | = | 194 | 43 | 20 |
| Half Sum ——— ZS | = | 19 | 17 | 35 |
| Half Sum ——— PS | = | 14 | 42 | 25 |
| Half Sum ——— PZ | = | 63 | 21 | 40 |

| | ° | ′ | ″ | | |
|---|---|---|---|---|---|
| Add together | | | | | |
| Log. of the Sine of | 14 | 42 | 25 | = | 9,40463 |
| And Log. of the Sine of | 63 | 21 | 40 | = | 9,95126 |
| And Double the Radius | | | | = | 20,00000 |
| All three | | | | = | 39,35589 |
| Add also together Log. Sine of PS $= 82^{\circ}.38' 20''$ | | | | = | 9,99642 |
| And Log. of the Sine of $19^{\circ}\ 17'\ 35''$ | | | | = | 9,51903 |
| These two equal to | | | | = | 19,51545 |
| Take this second Sum out of the first: the remainder is | | | | = | 19,84044 |
| Its half is | | | | = | 9,92022 |
| | | | | | = Tangent $39^{\circ}\ 46'$ as before. |

Accordingly its double $= 79^{\circ}\ 32$ is the angle ZPS, which was sought; and in time, as before $5^{h}\ 18'$.

*N.B.* In my *Ephemeris* or Scheme of Configurations, I had not room for the setting down the *Utmost Elongations* of these Planets. So I

have omitted them there intirely. And indeed, they being of no particular uſe to any but to ſome few curious Aſtronomical Obſervers, who are furniſhed with very long Teleſcopes, and very good Micrometers, and this at Land, and for a little time only; it was no way neceſſary to inſert them. As for the *Eclipſes*, they are to be all noted there. Thoſe of the firſt are from my own calculations: which almoſt always very nearly agree with Mr. *Weaver*'s, ſo far as I have tried them by Mr. *Pound*'s Tables; but corrected, as already explain'd. The calculations of the II$^{d}$ and III$^{d}$ are taken from Mr. *Hudſon*'s Catalogue of them, lately publiſhed in our *Philoſophical Tranſactions* for this year. The *Conjunctions* of thoſe Planets are alſo noted: all thoſe I mean that are not beyond the Scale of my Longitude Sector, nor very remote from *Jupiter*: The reſt are very few, and of little uſe for the diſcovery of the Longitude. And this indeed, is, I think, the very firſt time that ever thoſe *Conjunctions* have been foretold by Aſtronomers. And as for the *Occultations*, I have done what the Scale of my *Scheme of Configurations* would admit; I mean, I have ſet down the times of all the Geocentrick *Conjunctions* on this ſide *Jupiter*: which is the middle time between their *Immerſions* and *Emerſions*, which are alone viſible; and which, upon the Subſtraction, and Addition of their *Semidurations*, as ſtated under the V$^{th}$ *Lemma* foregoing, directly give the times

of

of thoſe *Occultations.* As do the *Oppoſitions*, there always noted alſo, by the like ſubſtractions and additions of *Semidurations*, give their *Immerſions* and *Emerſions* beyond *Jupiter* alſo. I mean, all this is actually noted on the *Ephemeris*, or *Scheme of Configurations*, without any farther trouble of Calculation on ſhipboard whatſoever. Which *Ephemeris* therefore I look on as one of the principal advantages that can be propoſed, in order to facilitate this great diſcovery of the Longitude, both at Land and Sea.

*N. B.* We have no occaſion for Mr. *Barſtow's* Quadrant in the diſcovery of the Longitude, but when the horizon is ſo hazy, or has what the Seamen call ſuch a *bank* of vapours, as hinders them from ſeeing the Sun, Moon and Stars, either riſe or ſet. Otherwiſe the time at the Ship, is beſt of all known by thoſe riſings or ſettings: which is at no altitude from the horizon, or at 90° from the Zenith (allowing the refraction) and is readily found by the foregoing, or the like trigonometrical Calculations: which are well known to thoſe that have learned the art of Navigation. Nor will it be improper to uſe the Longitude or other Teleſcopes in thoſe caſes: ſince thoſe Teleſcopes will afford a view of thoſe riſings and ſettings oftener, and more nicely than when the bare eye, how ſharp ſoever, is truſted in ſuch Obſervations.

XI. *To*

## XI.

*To find the Longitude of a Ship at Sea, during those six weeks in thirteen months, while* Jupiter *and his Planets are invisible to us.*

This is to be done, in general, by the *Appulse* of the Moon to any fixed Star in Dr. *Halley's Zodiack*, or by any of their *Occultation* by the Moon, in the manner following. Having placed the 28 pins, at the places of the Moon on this *Zodiack*, as they were each day, at noon, in the Meridian of *Greenwich*, taken from Mr. *Parker's* or Mr. *Weaver's Ephemeris*. Note what time the Moon's center will arrive at the Star you intend to observe, supposing the Moon had no Parallax; and this by measuring the distance of the Star from the Noon foregoing, and comparing it with the intire distance then from noon to noon, by the like measure; according to the following analogy. As the number of Inches belonging to the intire Day : is to 24 hours, or 1440 Minutes therein contained :: so is the number of Inches from the foregoing Noon, to the place of the Star : to the number of Hours and Minutes from the Noon foregoing to the time of the Moon's Conjunction with the Star. After this, take your Zodiack, of the largest scale, as including a portion of 15 degrees only, and place thereon the Star, or a point to represent it, from the Table of the Longitudes and Latitudes

tudes of these Stars exhibited on the backside of that portion of the Zodiack, and, by moving its larger fictitious Moon, correct the former time of Conjunction: which time will usually be six times as exact as the first time, because of this scale six times as large as the other; then will you have the very hour and minute of their Conjunction, so far I mean as the Moon's present Theory can afford it. And all this upon the supposition of no parallax; or when the Moon is in the Zenith of the ship, at which time all such Parallax intirely vanishes. And so far my *Ephemeris* of Configurations will guide you; because I shall insert the time of such Conjunctions into it, during the Interval between the disappearing of *Jupiter*, and his appearing again, for the Meridian of *Greenwich*. The rest must be done on shipboard, as under the Note following.

*N. B.* In order to gain the visible place of the Moon, and the true time and duration of this visible *Conjunction* or *Occultation*, even upon the allowance for the Parallax, in all places whatsoever, proceed after the following manner. Take a celestial Globe, and mark on it the point where the Moon is supposed to be at her Conjunction with the Star from the Zodiack, according to the largest scale; then rectify your Globe to the Latitude of the Ship, and, as near as you can, to the time of the night at the meridian of the Ship when that Conjunction would happen, without allowance

for

for the Parallax. Draw an occult line from the Pole of the Ecliptick through that point downward, as also another from the Zenith the same way: Measure that Angle, and make an Angle equal to it with the line perpendicular to the Ecliptick, and either eastward or westward as the position of the Ecliptick on the Globe will direct you, and this through the corresponding point on that portion of the Zodiack, and towards the Horizon. Note the distance of the point representing the Star from the Zenith; then set on this Line from the point representing the Star the intire Parallax of the Moon belonging to that distance from the Zenith. This will determine the very point of the apparent place of the Moon's center, on allowance for her Parallax; take that distance parallel to the Ecliptick, or rather to the Moon's way, which near the Nodes may be a small matter different from the other. This will be the *Parallax in Longitude*, and apply it to the proper scale for minutes of degrees in an hour of time, in proportion to the Moon's velocity in degrees or minutes belonging to that day; which is easily gathered from Mr. *Parker*'s, or Mr. *Weaver*'s *Ephemeris:* Add, or substract this difference, as the Globe will direct you, to, or from the time found before, and you will gain the true time of the Moon's apparent Central Conjunction with the Star at the Ship; and, by moving your fictitious Moon both forward and backward, you will

gain

gain the true times of the *Immersion* and *Emersion* of the same Star; which true time of the central Conjunction, when compared with the true time at the Ship, to be gained, as before, by Mr. *Barston*'s Quadrant, or otherwise, will give you your *Longitude from Greenwich*. But a very few hours instruction, *vivâ voce*, with the proper Instruments before you, will make this practice much easier to every curious Mariner, than any bare words whatsoever.

*N. B.* Concerning these methods of discovering the Longitude in general, both at Land and Sea; and how necessary it is that the Charts of the Sea Coasts be first of all corrected by the same methods; take Mr. *Witty*'s, or Mr. *Hodgson*'s words, in Mr. *Hodgson*'s *System of the Mathematicks*, Vol. I. pag. 384, 385. It is well known, says that Author, that "If "never so easy methods for finding the Lon-"gitude at Sea were proposed, they could not "be put in practice with any desirable success, "till the Longitude of the Sea Coasts were "better determined. For most certain it is, "that the surer any man is of the Longitude "of the place he is in at Sea, the surer he is "to miss the place he is design'd for, if the "Longitude of that place be not truly deter-"mined. So that if the worst of the methods "hitherto proposed be not practicable at Sea, "yet it cannot be denied but that they are "practicable at Land; and therefore the first "thing necessary to be done is to have all our

" Sea Coasts better settled, and new Sea Charts
" form'd. Let them attempt this first, and I
" doubt not but the Success will encourage
" them so much, that they will readily find
" means to put it in practice at Sea. For
" things that we are unacquainted with gene-
" rally seem more difficult than really they
" are; and Use very often renders those things
" easy, which at first sight we thought impos-
" sible."

" 'Tis to the *French* Missionaries chiefly that
" we owe the knowledge we have of most of
" the Sea Coasts, but more especially the *East*
" *Indies*, and the coasts of *China*. — And is it
" not a severe Reflection upon us, who want
" no means, and who trade almost to every
" part of the habitable World, that in three
" seven years scarce three Observations have
" been made by which the true Longitude of
" any of the places they have been in can be
" truly determined?"

— " I have often heard the Government
" blamed, for not sending two or three ships
" abroad to put the methods that have been
" proposed in practice, and thereby bring us
" such a treasure of Observations, as might
" enable us to draw new Maps of the Sea
" coasts."

Take also Dr. *Halley*'s words, to the same purpose, out of *Philos. Transact.* N° 354. which are these. " Of all the methods hither-
" to proposed for finding the Longitude of
" places

" places for Geographical uſes, none ſeems
" more adapted to the purpoſe than that by
" the *Occultations* of the fix'd Stars by the
" Moon, obſerved in diſtant parts. For thoſe
" *Immerſions* of the Stars, which happen on
" the dark ſemicircle of the Moon, and their
" *Emerſions* from the ſame, are perfectly mo-
" mentaneous; without that ambiguity to
" which the Obſervations of the Eclipſes of
" the Moon, and thoſe of *Jupiter*'s Satellites
" are ſubject. Beſides, whilſt the Moon is
" horned, and her weaker light leſs dazzling,
" an ordinary ſhort Teleſcope, ſuch as by ex-
" perience is found to be manageable on ſhip-
" board, ſuffices to obſerve theſe moments,
" even in the Occultation of very minute
" Stars. On which account this way ſeems to
" bid faireſt for the deſired Solution of the
" grand Problem of finding the Longitude at
" Sea. But ſince it would be needleſs to en-
" quire exactly what Longitude a ſhip is in,
" when that of the port to which ſhe is bound
" is ſtill unknown, it were to be wiſhed that
" the Princes of the Earth would cauſe ſuch
" Obſervations to be made in the ports, and
" on the principal Headlands of their domi-
" nions, each for his own, as might once for
" all ſettle truly the limits of the Land and
" Sea."

Take alſo the ſame Dr. *Halley*'s words at the bottom of his *Zodiack*. " The principal
" deſign of this Map is to foreſee the Appli-

"cations of the Moon to the fixed Stars. "These being duly observed on shore, would "be of great use to ascertain the Longitude "of places, and to verify the Charts of the "coasts of the Ocean; and until that be done, "the Longitude at Sea (for which the Parlia-"ment of *Great Britain* has provided so ample "a reward,) if found, would be of little ser-"vice. But the Sea Charts being thus once "perfected, the same Appulses of the Moon "to the fixed Stars would determine, by the "only practicable method, the true bearing "and distance of a ship at Sea from her Port, "without any regard to reckoning; which is "the thing required."

*N. B.* If, after all, the Reader be desirous of knowing to what degree of exactness these two methods by *Jupiter*'s Planets, and by the Moon's Appulse to the fixed Stars, are already capable of discovering the Longitude at Sea; and to what farther degree they may probably be advanc'd hereafter; I venture to say, as to the former method, by *Jupiter*'s Planets, that since Monf. *Cassini*'s own original Tables, published by Dr. *Halley*, in the *Philosophical Transactions*, N° 211. upon the comparison of the Theory of the I$^{st}$ or innermost Planet, with many good and certain Observations, scarce ever then err'd above 3′ or 4′ of time: since Sir *Isaac Newton* has inform'd us long ago, from Mr. *Flamsteed*'s Letters to him, that the Eclipses of the same Planet never then differed from his Theory by

2′ of

2′ of time: that in the outmost the error was little greater; and in the outmost but one scarcely three times greater: [or scarcely 6′.] *System of the World*, *Eng. Ed. pag.* 16. Since Mr. *Hodgson* has, long after that, assured us, from the comparison of 244 of its Eclipses, with his Tables, for 54 years together, that 74 of them do not differ 1′ from the Tables he makes use of; that 127 do not differ 2′; that 181 do not differ 3′; that 214 do not differ 4′; and that the rest do not differ above 5½. *Philos. Transact.* N° 436. [wherein above half are within 2′, and almost 8 out of 9 within 4′.] Since Mr. *Bradley* also reckons no more than 5′ 10″, error in the same Eclipses, *Transact.* N° 394. And since Mr. *Bradley* informs us farther, that the errors of the III^d Planet are also small: since they therefore do all agree that none but the II^d errs much from the Tables: And since withal it now appears that the *Conjunctions* of these Planets with one another are more numerous, and more nicely to be discovered and observed than the *Eclipses* themselves; I conclude, that this method, if followed with due care, and if the II^d Planet be not yet made use of, may generally discover the Longitude; at least *in the Latitude of Great-Britain*; within one degree of a Great Circle, or 60 Geographical Miles already, which is here within 7′ of time. And there is great reason to hope, that after good Observations of a few intire Periods of the three innermost, or

in

in a few 14⅓ months. (See *Corollary* (2.) after the XI<sup>th</sup> Lemma foregoing) the same Longitude will be hereby gradually discoverable to 50, nay, to 40, nay, to 30, nay, perhaps, at length, to 20 such miles; which last number implies a degree of exactness almost beyond the utmost desires and expectations of Astronomers.

As to the latter method, the Appulse of the Moon to the fixed Stars, take its present degree of exactness from Dr. *Halley*'s own words, at the bottom of his Zodiack; which are these: "In this method we must suppose the inequalities of the Moon's motion known. When perhaps the best numbers we hitherto have may err a few minutes; tho' scarce ever enough to produce in practice an error of above 40 Leagues [= 120 miles] And this, 'tis likely, may be amended if diligent Observations be made. Of which this Zodiack is very proper to notify the occasion."

And after all, I shall, myself venture to add this farther; that if once the Theory of the Moon's motions be brought to perfection, (to which Mr. *Flamsteed*'s and Dr *Halley*'s labours have greatly contributed;) this method by the Moon may, by degrees, be not much inferior in accuracy to the other by *Jupiter*'s Planets. Yet that the Period of the motions of these Planets necessary to be intirely observed, being no more than 14⅓ months, as we have already proved under

under Lemma VII. foregoing: while that of the Moon is known to be full eighteen years: the Theory of *Jupiter*'s Planets is likely to be brought to perfection much ſooner than that of the Moon. It is alſo to be farther remarked, that the Opportunities for obſerving either an *Eclipſe*, or *Occultation*, or *Conjunction* of *Jupiter*'s Planets will always be much more numerous, than thoſe for obſerving the Appulſe of the Moon to fixed Stars; and on that account will ever be much more advantageous to us in the diſcovery of the Longitude, both at Land and Sea.

I conclude the whole, as I have done upon two former attempts for the diſcovery of this *Longitude*, with my hearty wiſhes, *as a Man*, that this my deſign may tend to the common benefit of *Mankind*; as a *Briton*, that it may tend particularly to the honour and advantage of this my *Native Country*; and as a *Chriſtian*, that it may tend to the propagation of our *Holy Religion*, *in its original purity*, throughout the World.

London, July 6.
1738.

WILL. WHISTON.

## ERRATA.

PAG. 23. line 3. dele *in* and read *Conjunctions*. pag. 26. line 14. read *in: a few periods of* 14½ *months*. pag. 65. line 16. read *Determinations*. pag. 96. line 12. Add this (A groſs ſolution being firſt made by the Celeſtial Globe, if any ſuch be in the Ship, to prevent all fundamental miſtakes:) pag. 62. line 24. add, I mean this on account of the breadth of the Eye-Glaſs of 1½ inch only. While the breadth of the ſmall reflecter, of 2 inches, affords us room for near 4 degrees more; without our loſing the ſight of Jupiter and his Planets.

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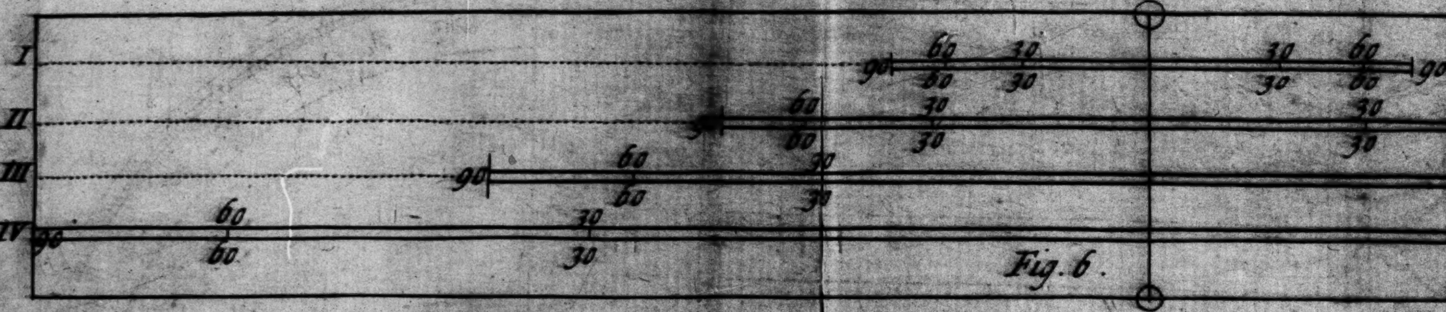


Fig. 6.

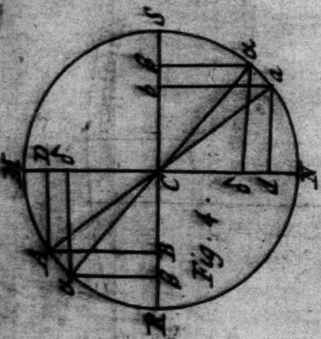
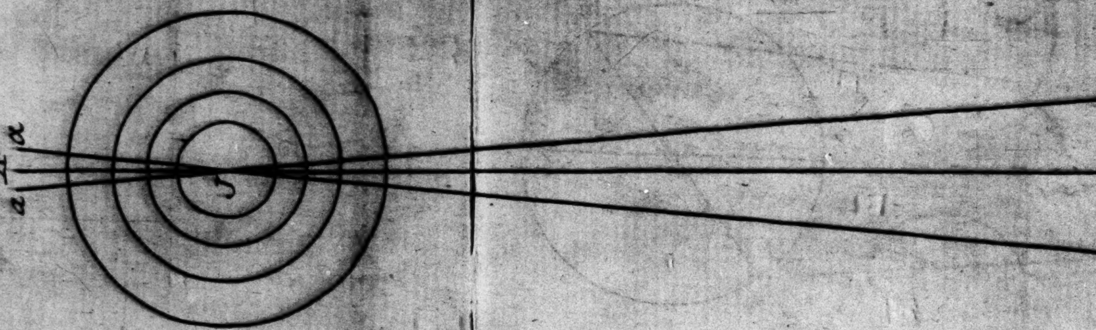
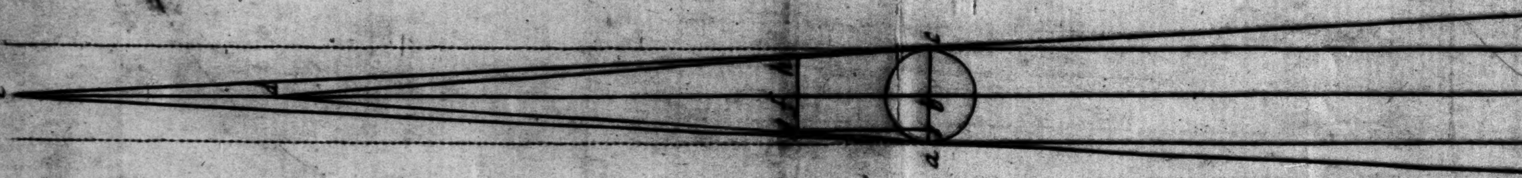


Fig. 4.





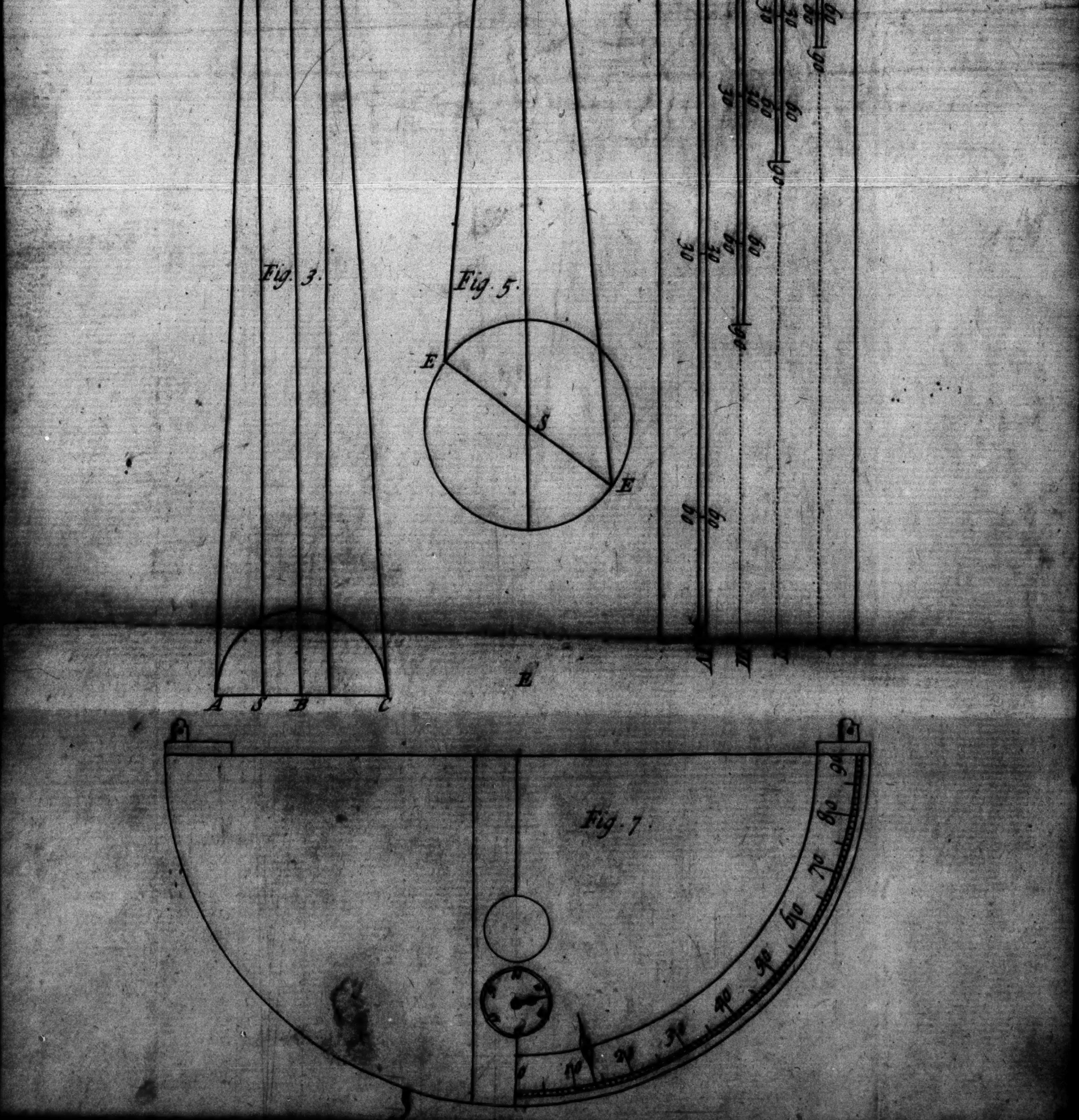


Fig. 3.
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